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FROM THE DEPARTMENT OF ORTHOPAEDIC SURGERY, SAHLGRENSKA SJUKHUSET, GÖTEBORG, SWEDEN (HEAD: PROFESSOR CARL HIRSCH) AND THE DEPARTMENT OF SURGERY, LASARETTET, UMEÅ, SWEDEN (HEAD: DOCENT GUNNAR REDELL)

A NEW APPARATUS FOR THE MEASUREMENT OF THE COMPRESSION BETWEEN TWO BONY SURFACES AND A CONSTRUCTION FOR COMPRESSION IN FRACTURES OF THE FEMORAL NECK

A preliminary report

By

NILS RYDELL

Compression and bony healing

The force of compression between the surfaces of a fracture are considered to promote the union of fractures. Opinions are divided as to whether it is only the better adaptation + fixation derived from the compression which is of value (*Bagby et al.*) or whether the pressure directly affects osteogenesis (*Charnley, Key*). The advantages of different compression forces have also been subject to discussion. Many consider that normal muscle tone gives optimal compression for the healing of fractures (e.g. *Pauwels*) and that what is required is to transfer cutting forces to compression forces (*Eggers et al.*). *Friedenberg et al.* have carried out experiments on the effect of compression on the bony healing in fractures of the ulna in dogs. They found that excessive compression delayed union and that the ulnar fractures in the experimental dogs united best with a compression force of 12–18 pounds.

A new method for the measurement of compression between two bony surfaces

It has not previously been possible to measure the applied load between two bony surfaces. This has become possible by using a method based on the principle that the electrical resistance varies during com

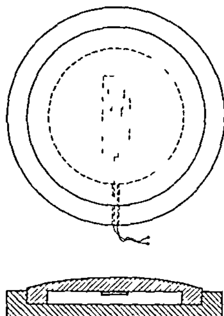


Fig 1
Constructional drawing of small compression container

pression or traction of this material because of changes in its dimensions. These variations can be determined using a measuring bridge the changes being proportional to the force producing compression or tension

Resistances called strain gauges have previously been used during measurements of the effects of forces on bone (*Hirsch* etc) In the present work the aim has been to construct an apparatus which could measure the compression forces between two bony surfaces. This was done in such a way as to allow the testing of specimens with osteosynthetic material (medullary nail Charnley's appliance etc) Furthermore it was necessary that the reading was not affected by oblique loading or that only one sector of the construction surface was loaded First small containers were made each fitted with a straingauge (Fig 1) These containers were put in special holes in a metal disc (Fig 2) a flat metal disc was put against the plate with the containers and this apparatus was placed between two bony surfaces The pressure was read off from every container The idea was that both quantitative and

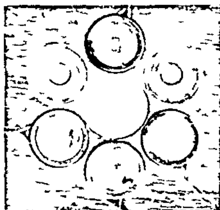


Fig 2
Compression containers and metal disc with hollows for containers

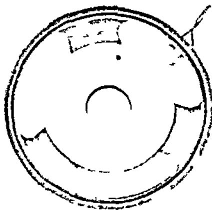
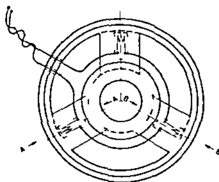


Fig 3
The compression container used in the experiments



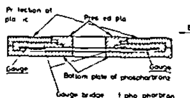


Fig 4
Constructional drawing of the compressi n c ntainer used

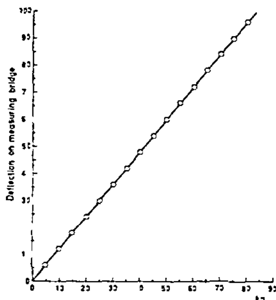


Fig 5
Loading curve of the compression container

qualitative measurements could be obtained by reading off which containers were loaded the most However the sources of error in the quantitative measurement were too great and after a few unsuccessful constructions an apparatus fit for use was produced (Fig 3) A special surface absorbs the compression force and conveys it to a middle disc on which are placed three strain gauges in series as shown in the diagram (Fig 4) A plastic cover partly protects the contents of the container from dirt The container for measuring compression was first tested with the help of weights and later greater forces with the help of an Amster testing machine The load was increased 5 kg at a time and each time there was a deflection of 6 divisions on the bridge (Fig 5) A graph of these measurements gave a linear response and only sometimes was there a deviation of 1 division Tests were carried out before and after each experiment

During experiments with Charnley's screw the high strength values found by *Putti* and referred to by *Charnley* were not always obtained The screw slipped out of the head during a number of experiments with a traction force of as little as 16 kp

Methods of osteosynthesis for fractures of the femoral neck

In spite of the fact that many attempts have been made to obtain compression of fractures of the femoral neck by osteosynthesis it is still most common to use a 3 or 4 flanged nail usually combined with a plate which is screwed tightly into the lateral side of the femur Other constructions have been recommended e g the V shaped nail and the H shaped as suggested by *Frankel* Constructions made to produce a compression between the fracture surfaces have often lacked that resistance to rotation possessed by a flanged nail

Compression is often produced by a screw arrangement with the disadvantage that a rotation displacement can occur when the screw is tightened This is the case with the appliances of *Charnley* and *Godoy Moreira* With Cleary s construction the attachment in the head consists of two wings which open out but this as with the instrument described by *Hardinge et al* lacks the resistance to rotation displacement possessed by the flanged nail Many such constructions also lack a support which can be fixed to the lateral surface of the femur (e g Putti s screw) It is generally accepted that fixation of a medial fracture of the femoral neck requires greater strength than that given by nails without plates (*Dickson* who also considers that bone chips are valuable *Eaton Janl en Jewett Kurl Maurer*) Furthermore it is considered that a reliable osteosynthesis must allow a load of at least 300 kg without producing forces other than compression in the plane of the fracture and that the nail should be driven in relatively steeply through the neck up into the head (*Dubois Eaton Massie* etc) An ordinary Smith Petersen nail usually gives way in the lateral cortex with a load of about 80 kg Multiple nails which are said to be superior to 3 or 4 flanged nails (*von Bahr Moore Modny et al Nyström*) are not mechanically better than flanged nails (*Frankel*)

To retain the advantages of the flanged nail and still obtain compression in the plane of the fracture telescopic nails have been constructed (*Luck* etc) The telescopic movement is allowed only for shortening There are other advantages with telescopic nails Only one nail length is needed and the not unusual complication of penetration of the joint when the nail is fixed by a plate is avoided by the telescoping Many are of the opinion that with these appliances a physiological compression is obtained through muscle action The intermittent compression suggested by some is unlikely to occur since telescoping can only take place in one direction In a number of cases the telescope construction does not function when osteosynthesis is complete

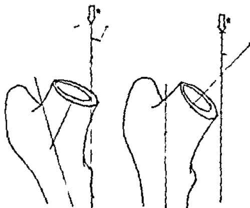


Fig. 6.
Proximal femur. V = angle between the force and the long axis of the femoral neck.

Strains of force in the neck of the femur

During loading of the head of the femur the forces are transmitted through the neck in the form of a compression force through the inferior cortex and a traction force via the superior cortex. *Hirsch et al.* have shown the minor importance of the spongiosa from the point of view of strength in this region. Experimentally a compression force can be produced through the upper cortex if the angle V between the direction of the force and the axis of the neck is small (Fig. 6). First when the angle V approaches 0 the force of compression in the superior cortex is of considerable size and at the same time the compression stresses in the inferior cortex diminish. It is supposed to be anatomically impossible to obtain a traction force in the inferior cortex in vivo but this has been successfully carried out in vitro by means of static loading of the greater trochanter (*Evans*). As early as 1876 *Rauber* showed that bone has a greater strength against compressive forces than against traction forces. Bone has the least strength against torsion and shearing forces (*Johansson*). During static loading of the femoral neck not only the above mentioned traction and compression forces play their part but also shearing and torsion forces. A mechanical support should not only prevent the action of injurious mechanical forces but should also be able to produce forces which counteract the injurious forces. In the theory of strength of material is used the term pre-load which has the opposite direction to an injurious force which will later act on the construction. Pre-load exists physiologically in vivo and has been demonstrated by *Pauwels* but the technical term has not previously been used in biological work. *Pauwels* showed that muscles have the

ability to oppose injurious forces. In a model of the femur a load corresponding to the weight of the body produced a traction force of 69 kg/cm on the lateral side of the femur and a compression force of 83 kg/cm on the medial side of the femoral diaphysis. Later a force in the form of a traction brace was applied to the site of the greater trochanter on the model of the femur and the traction force was reduced to 8 kg/cm and the compression force to 48 kg/cm. The photo elastic technique used in the experiments of *Pauwels* and others has been the subject of criticism. This operates with solid materials which do not correspond to hollow bone of heterogeneous composition. The conclusion is maintained that muscular forces reduce the stresses from the body weight and do not as asserted by *Grunewald* increase the bony strains from the mechanical point of view. Even with well functioning telescopic nails it is not possible to give back to the superior cortex its ability to increase the stability of the neck. It is a traction force which acts on the upper cortex. Only if the fracture is reduced in a strong valgus position as *Massie* suggests is a compression force obtained in the upper cortex but instead good adaptation in the spongiosa and lower cortex is lost. It may be questioned whether the compression force in the upper cortex is lasting. Even with a steeply inserted nail I have not succeeded in obtaining any compression value in the upper cortex using a straingauge when the head was loaded. In cases where the head was fixed in light abduction an impaction occurred in the form of an adaptation between the fracture surfaces with very small loading in spite of a steep nail and a measurable compression in the lower cortex was read off which increased with loading. At first when the angle V in Fig. 6 was less than 10° compression was obtained in the upper cortex. During the experiment the femoral shaft was adducted at an angle of about 12° to the vertical plane.

In order to find out if an inserted femoral nail affects the direction of forces through an unfractured femoral neck experiments were carried out on unfractured bones with and without nails. There was no difference to speak of between the directions or size of tension and compression forces through the cortex of the neck. Experiments were also carried out on unfractured bone on changes in forces with different sizes of the angle V. The tension force in the upper cortex diminished greatly when the angle V was reduced and the compression force in the lower cortex diminished similarly but less. From this I have drawn the conclusion that the importance of the spongiosa for the strength of bone increases with compression forces.

Attempts to construct a new method of osteosynthesis

An osteosynthesis is desirable which produces a compression force through the upper cortex (a pre-load which acts against injurious directions of force) which does not prevent good adaptation in the whole fracture plane and which is so strong that it tolerates loads of at least three times the weight of the body. An attempt at such a construction has been made.

The choice of metal alloy is of great importance where it concerns operation material to be left in the body. At the present time there are really only two metal alloys to choose from: a non-ferrous steel called vitallium and 18-8 Mo steel. Vitallium has the advantage of being hard with a yield strength of about 58 kp/mm² and is also the metal alloy most resistant to corrosion in the human body. One disadvantage is the poor elasticity but most importance is the fact that vitallium is difficult to mould and all constructions must be made by precision casting. 18-8 Mo steel has a good resistance to corrosion and is easily moulded. A disadvantage is that it has a yield strength of only about 28 kp/mm². A steel can be strain hardened to increase its stability without changing its properties. *Scales, Shirley et al.* have shown that with alloys of the type 18-8 steel the resistance to corrosion is not related to its hardness. By strain hardening 18-8 Mo steel develops a yield strength of about 84 kp/mm². This value exceeds that for vitallium while the other advantageous properties of this steel remain. A strain hardened 18-8 Mo steel was therefore chosen.

A flanged nail (3-flanged, 4-flanged or H-shaped) gives better stability against torsional forces than other fixation types in fractures of the femoral neck. In addition impaction is not prevented. By combining a nail and a screw a stable compression osteosynthesis is possible. A screw of suitable length could be placed parallel with and cranial to the nail. The compression obtained in this way should affect mainly the upper cortex which is an advantage mechanically. The blood supply of the head may be threatened by two such large objects and the insertion of a screw-nail would be complicated. *Judet et al.* have shown that the head also depends on the neck for its blood supply and the ingrowth of vessels from the distal fragment of the neck may be prevented. Another possibility would be to insert a screw through the central canal of the nail which has no function after the guide wire has been withdrawn. Earlier experiments have shown that for a screw to be fixed reliably in the head it must be inserted about 3 cm. Such a

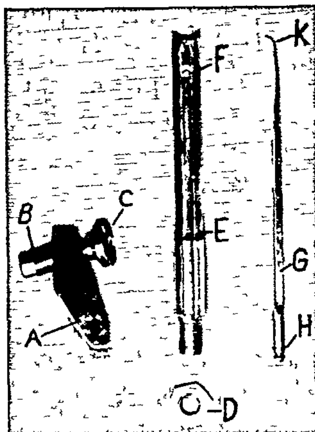


Fig 7

Instrument f r o te s nth is of fractures of the medial femoral neck. a = plate b = compre i n crew c = supporting plate against the tr chanteric area d = nut with n lon lock washer e = 4 flanged nail f = h le for spring pin g = pring pin h = lock ring k = the curve of the pin

construction is not reliable since the nail must also be inserted a sufficient distance into the proximal fragment of the head Another disadvantage is possible with the fixation of a screw in spongy bone As *Collins* showed a metal object left in a bone produces a cell reaction After only 6 days a fibrous cell membrane begins to form and the object gradually lies completely sequestrated from the bone by a fibrous membrane Especially if a remaining traction force affects the screw in a spongy bone an unreliable fixation is produced If a screw slips the length of one of its threads no power of fixation remains If instead an



Fig 8
The head of the femur with the distal part of the nail and the hooked pin



Fig 9
Roentgen film of the instrument and compression container

attachment can be placed inside the head which can be lowered from the nail in the form of a hook it becomes surrounded by healthy undamaged spongiosa in the direction of the nail. A successful attachment in the head has been made possible by providing the nail with a central canal which bends in a bow at a suitable distance from the tip of the nail and emerges at the upper side of the nail (Fig 7) between two wings and inserting an elastic pin of the same metal as the nail (Fig 7 g) but of such a size that it follows the curved shape of the canal and then continues as a bow into the bone (Figs 8, 9). A narrower central canal continues in the straight line of the wider canal to the tip of the nail. In this way a guide can be used during insertion of the nail. The elastic pin tolerates traction force of more than 80 kp when made of strain hardened steel and about 45 kp when made of ordinary 18 8 Mo steel. The part of the elastic pin which lies outside the nail bends when its tenacity is exceeded and with sufficiently large strain comes to be parallel to and along the surface of the nail. Only if a compression in the fracture is produced by tightening the pin is it exposed to stress. In this way a compression force of up to 80 kp can be applied.

To obtain a compression with the help of a pin a force must be applied to the lateral surface of the femoral diaphysis. A nut of the type used by *Pulli* would be the simplest. However a nut gives insufficient strength in osteosynthesis. During test experiments this only moderately

exceeded that obtained by an ordinary Smith Petersen nail The advantage was that the nail could not slip out of the femoral head but could follow the head during absorption of the femoral neck Combining the compression construction with a conventional plate which can be screwed tight length wise in the femoral diaphysis is relatively complicated The connection between the plate and the nail must be stable which it often is not (*Frankel*) The risk of the nail penetrating the joint with shortening of the femoral neck is considerable when using a nail plate If the plate is put in a cranial direction and is allowed to lean against the area of the greater trochanter a stable connection between the plate and the nail and a good point of support for the compression construction can be obtained and with shortening of the femoral necks the nail can slide out of the distal fragment In the present case the nail is prevented from sliding out of the femoral head because of the attachment to the head If the femoral neck is shortened the head of the compression screw can be exposed by an incision of about 1 cm in length (Fig 7 b) and again tightened The time for removing the screw can be decided from the x ray film The plate by which the screws comes in contact with the trochanteric area (Fig 7 c) is fitted on to the screw by a universal joint so that it can be supported by the surface of the bone independently of its shape The surface in contact consists of three projections which provide a good support even for a somewhat irregular bony surface Fig 7 shows the instrument It is easy to use First a guide wire is inserted in the usual way after the fracture is reduced anatomically The wire should be inserted relatively steeply 125 13) for the sake of stability and because the plate is then most easily applied Over the guide wire is bored a hole as big as the body of the nail This method has already been described by *Aronsson* A punch of the same dimensions as the nail with a body which guides in the bore canal and wings beginning at different levels are inserted This reduces the risk of splitting the cortex on the lateral side of the femur during insertion of the nail The nail is then inserted In a number of nails the body has been allowed to go forwards 4 mm in front of the wings In this way the nail follows the direction of the boring more safely This construction is analogous to the spiral screw and guide described by *Groth* Such a nail however is more expensive to manufacture The importance of adapting the fracture by means of an impactor already used by *Smith Petersen* has been emphasized by *Fyre Brook et al Jewett Johansson* and *Moore* After the impactor has been used it is often necessary to insert the nail further and then produce a

new impaction. In this way the fracture is well adapted. The spring pin is then inserted so that its springy tip (Fig. 7 k) points towards the hole between the flanges of the nail and it can be clearly felt when it springs out. The pin is then inserted with the help of a punch so as not to damage the head of the pin until a locking ring (Fig. 7 h) reaches the intended place in the nail. The insertion of the pin has never failed nor have the fragments been separated by it. The plate is then applied. The nut for this is supplied with nylon lock washer and the compression screw is tightened. There is a risk of tightening too much but it can be felt when sufficient tension is applied.

Experimental tests

An osteosynthesis carried out in this way and tested in an Amsler testing machine tolerates a load of over 300 kp without the appearance of a visible malposition in the fracture. When the load was 600 kp the fracture moved to a strongly varus position but in the region of the greater trochanter only a barely visible mark could be seen in spite of the fact that the force here must have reached over 1500 kp. The force is transferred to the surface of the bone in the direction of the compression screw via levers. The nails of 18/8 Mo steel which were used at first bent with high loads but when steel with a yield strength above 80 kp/mm² was used the nails were unaffected.

The compression which could be produced with nail-wire-plate was measured with the instruments previously described for the measurement of the compression force between two fracture surfaces. A compression force of about 70 kp was applied and after some minutes the pressure fell to about 50 kp and remained constant. The pressure was increased to about 85 kp, no further increase in compression could be obtained and a control roentgen picture showed that the part of the pin lying outside the nail began to straighten.

Two strain gauges coupled in series were glued onto both upper and lower sides of the femoral neck (Fig. 10) distal to the fractures line which was pointed at right angles to the long axis of the neck of the femur. Readings were taken from separate measuring bridges for the strain gauges on the upper and lower sides. An osteosynthesis was made with the new compression instrument. Readings on the measuring bridges (Fig. 11) showed a slight compression from the inferior cortex and a powerful compression from the superior cortex. When the spring was tightened even more the force through the inferior cortex remained



Fig 10
Two strain gauges coupled in series mounted on the under side of the femoral neck

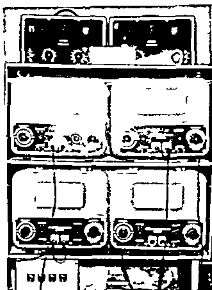


Fig 11
Philips measuring bridges

unchanged at its low level With very powerful compression it was also possible to read a slight decrease in compression in the inferior cortex The compression force through the superior cortex increased the more the spring pin was tightened The specimen was then put into an Amsler testing machine and the head loaded to 150 kp (Fig 10) During the experiment the angle of the femoral diaphysis to the vertical plane became about 12 There was a traction in the superior cortex which with a load of somewhat over 50 kp cancelled out the applied compression force The rise in compression in the inferior cortex was relatively small The load was discontinued and the same compression force was read off in the upper cortex as before the experiment The head was then loaded with 100 kp a powerful increase in compression was read off in the lower cortex when 50 kp was exceeded and a tension in the superior cortex was read off more than that which had neutralized the compression force Since the bone was fractured the latter force must have come by deformation of the tubular femoral neck because of a compression force in the inferior cortex The force was slight and was not obtained with all the specimens The load was discontinued and the same compression force was read off in the superior cortex as at the

beginning of the experiment. On the whole the same results were obtained with a load of 150 kp.

Twenty osteosynthesis in clinical cases of fracture of the femoral neck have been performed with this apparatus. Only nails made of 18 8 Mo steel have been used but in future they will be made of strain hardened 18 8 Mo steel.

The final design of the plate and compression screw have not yet been decided on; probably the size of the plate can be reduced without risk of insufficient stability.

SUMMARY

A new apparatus is described for measuring the total compression force between two fracture surfaces and a new term "pre-load" is introduced. By "pre-load" is meant a force which is directed opposite to a later injurious force. It is pointed out that the body musculature can develop a protective pre-load in the bony system and it is assumed that this is also the case with the neck of the femur.

An instrument is then described for osteosynthesis of fractures of the femoral neck where a compression force is applied in the plane of the fracture and is mainly directed so that it functions as a protective "pre-load". The intermittent pressure recommended by many occurs by an increase in compression with loading in the inferior cortex and a traction temporarily interrupts compression in the superior cortex partly or wholly.

RESUME

Un nouvel appareil de mensuration de la force totale de compression entre deux surfaces de fracture est decrit et un nouveau terme "precharge" est introduit. Par "precharge" on entend une force qui s'oppose directement a la force d'une lesion ulterieure. Il est releve que la musculature du corps peut developper une precharge protectrice dans le systeme osseux et il est presume que cela peut etre aussi le cas du col du femur.

Il est alors decrit un instrument pour l'osteosynthese de la fracture du col femoral ou une force de compression est appliquee dans le plan de la fracture principalement dirigee de maniere a fonctionner comme "precharge". La pression intermittante recommandee par beaucoup intervient par l'accroissement de la compression au moyen d'une charge du cortex inferieur et une traction qui interrompt temporairement la compression du cortex superieur partiellement ou completement.

ZUSAMMENFASSUNG

Ein neuer Apparat zur Messung der totalen Kompressionskraft zwischen zwei Bruchoberflächen wird beschrieben und ein neuer Ausdruck Voraufladung wird eingeführt Unter Voraufladung versteht man eine Kraft die einer späteren beschädigenden Kraft entgegen wirkt Man hebt hervor dass die Muskulatur des Körpers eine beschützende Voraufladung des Knochensystems darstellen kann und man nimmt an dass dies auch der Fall mit dem Hals des Femurs ist

Ein Instrument zur Osteosynthese von Brüchen des Oberschenkelhalses wird dann beschrieben mittels welchem eine komprimierende Kraft in der Bruchebene angewendet wird die hauptsächlich so gerichtet ist dass sie wie eine Voraufladung wirkt Der intermittierende Druck der von vielen anbefohlen wird entsteht durch eine Zunahme der Kompression mit Aufladung in der cortex inferior und einem Zug der zeitweise die Kompression in der oberen Cortex teilweise oder ganz aufhebt

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FROM THE ORTHOPAEDIC HOSPITAL OF THE INVALID FOUNDATION
HELSINGFORS. HEAD: A. LANGENSKIÖLD, M.D.

HAS EPIPHYSEODESIS IN ONE END OF A LONG BONE A GROWTH STIMULATING EFFECT ON THE OTHER END?

An Experimental Study

By

HENRIK V. A. HEIKEL, M.D.

Increased longitudinal growth of the long bones may occur as a result of infections, tumours or mechanical traumata such as implantation of foreign bodies into the bone or detachment of the periosteum of the diaphysis. The increase is inconstant, however. According to *Blount* (1) the acceleration will persist only while the stimulating factor operates and then the growth will continue at a normal rate. According to him the increase in length is permanent, since no retardation occurs later. Neither does the fact that the stimulated epiphyseal line fuses some months earlier than the contralateral result in any readjustment of the difference in length, since by this time growth in length has virtually ceased. In contrast to this opinion *Jansen* (3) stated that the effect appears to occur in the first few months after the procedure (Pease operation). Later the gain is more or less reduced.

Speaking of the effect of surgical procedures on the epiphyseal line *Blount* (2) suggested that the trauma which inhibited one epiphyseal line probably stimulated the other, a phenomenon which happens routinely in children. If his surmise is correct, then this is one of many factors influencing the result of epiphyseodesis aimed at readjustment of the length of the bone. Perusing the available literature on the subject I have not found any investigation on the subject of whether epiphyseodesis at one end of a long bone stimulates the epiphyseal line at the other end of the bone. The aim of the present investigation is to throw some light upon this matter.

MATERIAL AND METHOD

Normal curves for the contribution made by the different epiphyseal lines to longitudinal growth in man are lacking as are also acceptable reasons for the introduction of foreign bodies into the bone (to act as visible measuring labels in radiograms) in clinical cases. For these reasons the investigation was carried out on animals. Although Blount's method consisting of two separate procedures and the temporary introduction of foreign body (staples) might constitute a stronger stimulus, in the absence of staples suitable for the bones of young rabbits epiphyseodesis was performed according to a modification of Phemister's method.

On nine rabbits (originally 19, of which 10 died of an epizootic at ages of 1 to 3 months) small steel wire labels were introduced at the ages of 9 to 22 days under local anaesthesia into the diaphyses of the tibia and fibula. As I have shown earlier (4) such labelling does not have any measurable effect on the growth in length of the bone. Epiphyseodesis of the proximal epiphysis of the right tibia was carried out on four rabbits about 80 days old, on three about 110 and on two about 120 days old. Under local anaesthesia and without freeing the periosteum the epiphyseal plate was gouged and curetted from both the medial and the lateral side. The left tibia was left untouched for control.

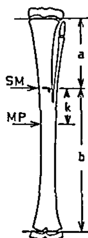


Fig. 1.

Schematic illustration of the method of measurement employed. SM = steel marker. MP = mid point of the diaphysis. k = correction factor. a + k = corrected length of the proximal part and b − k = corrected length of the distal part of the tibia.

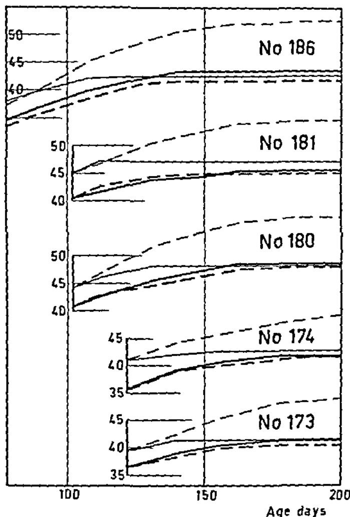


Fig. 4

Growth curves of the tibias of rabbits nos. 173, 174, 180, 181 and 186

——— = distal epiphysis of right tibia
— — — = distal epiphysis of left tibia
——— = proximal epiphysis of right tibia
- - - - = proximal epiphysis of left tibia

Three animals died before the end of the growth period and in one the label became detached from the tibia, thus only five animals could be included in the series. The animals were radiographed at 1 or 3 weekly intervals and at a constant focal distance (96 cm.). The measurement of the length in the radiograms was accurate to within 0.5 mm.

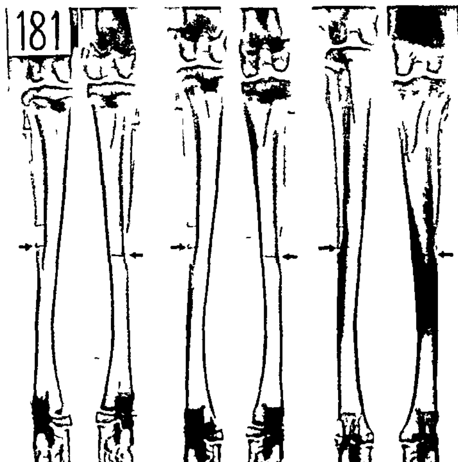


Fig 3

Rabbit No 181 The hind legs immediately one month and four months after epiphysiodesis of the proximal epiphysis of the right tibia The arrows indicate the position of the steel markers inserted in the diaphysis

On each radiogram the following measurements were made (see Fig 1) the distance from the label in the diaphysis (SM) to the proximal epiphyseal line of the tibia = a and to the distal epiphyseal line of the tibia = b The distance between SM and the midpoint of the tibial diaphysis (MP) was measured on the radiogram made immediately after labelling This distance k which is constant was added to the distance a and subtracted from b in all radiograms of the same tibia Thus a common starting point was obtained for the growth

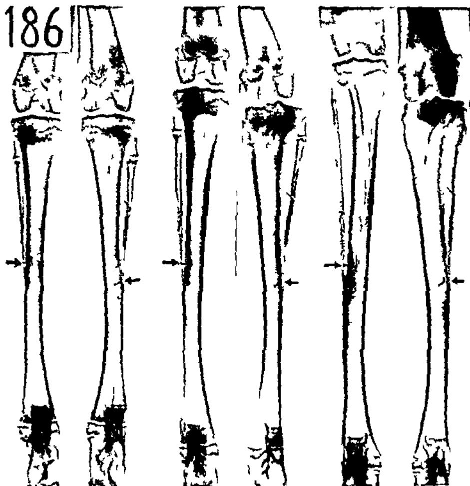


Fig 4

Rabbit No 186 The hind legs immediately one month and five months after epiphysiodesis of the proximal epiphysis of the right tibia The arrows indicate the position of the steel markers inserted in the diaphysis

curves of the proximal and distal epiphyseal lines the curves being drawn on the basis of the values thus corrected (Fig 2)

OBSERVATIONS

1 The longitudinal growth in the proximal end of the right tibia ceased within 10 to 30 days after epiphyseodesis

2 The longitudinal growth in the proximal end of the left tibia (the control) was normal as compared with the normal curve according to

Heikel (3) Thus a difference in length varying between 6 5 and 10 mm arose in the proximal ends of the tibiae (Figs 3 and 4)

3 The longitudinal growth in the distal end of the tibia was apparently neither temporarily nor permanently in any appreciable degree affected by the epiphyseodesis The growth curves were more or less parallel The growth in length in the distal end of the right tibia was the same as that in the left in one animal 0 5 mm greater in two animals and 1 mm greater than the left tibia in two animals The differences are so small that they can be considered to lie within the limits of normal variation and of errors in measurement

4 The relation between the growth inhibition in the proximal end and the growth increase in the distal end of the right tibia varied 0 and 1 7 5 (0 133) being 0 072 on average i e less than 1 10

5 The distal epiphyseal lines of both tibias closed at the same time

CONCLUSION

Epiphyseodesis carried out on the proximal end of the tibia of 80 to 120 day old rabbits has no effect upon the longitudinal growth at the distal end of the tibia or at most stimulates it quite insignificantly The question of the applicability of this result to clinical cases falls outside the scope of the present investigation

RESUME

Une epiphyseodese pratiquee sur l extremite proximale du tibia chez *des lapins ages de 80 a 120 jours n a aucun effet sur la croissance* longitudinale de l extremité distale du tibia ou la stimule au plus d une maniere insignifiante La question de l application de ce résultat en clinique sort du cadre de la presente enquete

ZUSAMMENFASSUNG

Eine am proximalen Tibiaende von 80 bis 120 Tagen alten Kaninchen ausgefuhrte Epiphyseodese hat keine Wirkung auf das Langenwachstum des distalen Endes der Tibia oder doch nur ganz unbedeutende Wirkung Die Frage der Anwendbarkeit dieses Ergebnisses auf klinische Falle liegt ausserhalb der Aufgabe der vorliegenden Untersuchung

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NORRBACKAINSTITUTET, STOCKHOLM

ARTERIOVENOUS FISTULA FOR DISCREPANCY IN LENGTH OF LOWER EXTREMITIES

By

T. HIERTONN

The surgical construction of an arteriovenous fistula between the femoral artery and vein has been used for the purpose of equalizing leg length differences in 5 cases of poliomyelitis. The local and general effects in these cases have been studied for 10 years.

BACKGROUND AND DEVELOPMENT

Knowing the growth stimulating effect often produced in cases of congenital vessel abnormalities with arteriovenous communications, it was an easy step to the surgical imitation of such a condition by creating an arteriovenous fistula near the actual growth zones in the extremities with retarded length. *Janes & Musgrave* (1949, 1950) showed in experimental studies the growth stimulating effect of a surgically produced fistula between the femoral artery and vein in puppy dogs. The method was applied clinically in the Mayo Clinic (Dec. 5, 1950). According to *Janes* (1958) 44 children have been operated there. The method is also under clinical trial in Toronto (*Mustard* 1957). At the orthopaedic clinic of Karolinska Institutet the method was first clinically applied in the autumn of 1950, on a suggestion from *Ph. Sandblom*. At the same time in collaboration with *A. Obel* a study was made of the arterial and venous pressures and skin temperatures adjacent to 3 and 4 armed arteriovenous anastomoses in dogs.

PATHOPHYSIOLOGY

A direct communication between the high pressure arterial system and the low pressure venous system brings about an increased blood volume passing through this region. The total blood volume and the

heart's minute volume are increased and the involved artery, vein and fistula can be dilated. The situation and size of the fistula and to a certain extent the duration of patency are of considerable importance in the local and general symptoms. According to *Holman* (1937, 1955) a fistula of 1–1½ cm in diameter between the aorta and the inferior vena cava invariably causes fatal cardiac insufficiency, whereas a fistula of the same size between the femoral vessels is never immediately deleterious. A strikingly rich local collateral circulation is obtained in the neighbourhood of an arteriovenous fistula because of the hemodynamic changes. In the tissues far distal to an arteriovenous fistula, on the contrary, the arterial circulation can become fundamentally reduced depending on how much arterial blood is shunted past the area. This in combination with the impeded venous return explains the peripheral ischemia and stasis which can occur in both congenital and acquired arteriovenous fistulae.

TABLE I

Case number	Sex	Polio at the age of	Paralytic distribution	Discrepancy in length of lower extremities at operation Tape measure	Age at operation years
1	M	[illegible] years	Left hip, knee and foot	7 cm	1[illegible]
2	F	1 year	Right hip, knee and foot	9 cm	11
3	M	3 months	Left hip, knee and foot	4 cm	9
4	M	3 months	Left hip, knee and foot	5 cm	6
5	M	1 month	Right hip, knee and foot	5.5 cm	6

MATERIAL

During the time 23/8 1950 until 8/2 1951 an arteriovenous anastomosis between the femoral artery and vein has been performed on 5 children with retarded growth in one lower extremity following polio.

The ages, sexes, distribution of the pareses and the differences in the leg lengths are shown in Table I. The leg lengths were measured partly with X-ray, partly with a tape measure and partly evaluating the discrepancy by placing wooden blocks under the short leg when standing until levelling of the pelvis is obtained. Orthoroentgenography was first introduced in the clinic in 1953 and before this leg length was measured from a simple survey film of the thigh and foreleg respectively. If not otherwise stated the figures for leg length in this

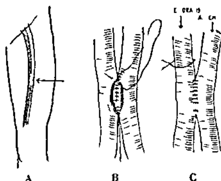


Fig 1

A The site of the fistula between a and v femoralis —*B* The posterior line sutured with adventitia to adventitia —*C* The anterior line sutured with intima to intima Black silk around vein proximal to the fistula as guide to next stage

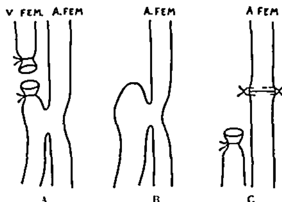


Fig 2

A Stage 2 Ligation and transection of vena femoralis proximal to the fistula after 3 weeks —*B* The 3 limbed a v fistula Note the dilatation of the vein — *C* Operative closure of the fistula and arterial reconstruction

article were obtained by clinical measurement All cases were followed before operation regarding leg length and they showed a progressive increase of the discrepancy

OPERATION TECHNIQUE

Stage 1 The femoral artery and vein were dissected free just above the middle of the thigh (See Fig 1) After clamping with soft vascular clamps adjacent longitudinal incisions about 10 mm long were made

heart's minute volume are increased and the involved artery, vein and fistula can be dilated. The situation and size of the fistula and to a certain extent the duration of patency are of considerable importance in the local and general symptoms. According to *Holman* (1937, 1955) a fistula of 1–1½ cm in diameter between the aorta and the inferior vena cava invariably causes fatal cardiac insufficiency, whereas a fistula of the same size between the femoral vessels is never immediately deleterious. A strikingly rich local collateral circulation is obtained in the neighbourhood of an arteriovenous fistula because of the hemodynamic changes. In the tissues far distal to an arteriovenous fistula, on the contrary, the arterial circulation can become fundamentally reduced depending on how much arterial blood is shunted passed the area. This in combination with the impeded venous return explains the peripheral ischemia and stasis which can occur in both congenital and acquired arteriovenous fistulae.

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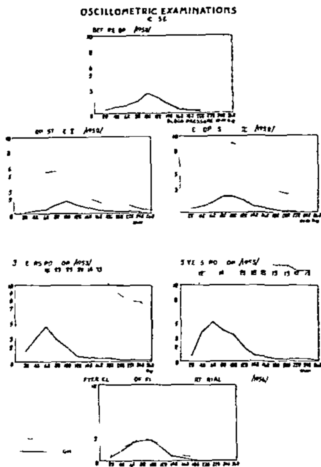


Fig 3

Oscillometric examinations After construction of a v fistula in the left thigh strikingly increased oscillometric readings are obtained Note normalization after closure of fistula

Oscillometric studies[1]

Before operation there were somewhat lesser readings on the paralysed short side as compared to the unaffected side both over the thigh and foreleg After the first stage of the operation an essential increase of the pulsations was detected over the thigh but those over the foreleg continued to be small and indeed were less than preoperatively After stage 2 the pulsations over the thigh became greater than normal but

[1] Performed in the Physiotherap Department of the Kar linska sjukhu et



Fig 4

Phonoarteriogram with microphone placed over arteriovenous fistula Note the continuous character of the murmur Upper tracing ECG Lower tracing phonoarteriogram (Case 2 three months postoperatively)

Fig 5

Phonoarteriograms over the fistula (A) in 1955 (B) in 1956 (Case 4)

A There is a loud high frequent murmur beginning just under the middle of T Wave of ECG and ending in protodiastole Another murmur of much less frequency and intensity begins with P wave and goes on into the first murmur

B There is only one late systolic murmur The amplitude is lower than before These changes correspond to partial thrombosis of vena femoralis

over the foreleg they remained small for a time Later the readings were greater than normal even over the foreleg The curves shown in Fig 3 (case 1) are characteristic After closure of the fistula and repair of the artery the oscillometric readings became normal and equal on both limbs

Thrill murmur pulse rate and Branham s sign

A palpable thrill and a clearly audible murmur almost of machinery type were present over the arteriovenous connection in the thigh These signs result from the turbulence in the blood streaming through the relatively small fistula into the dilated vein The systolic accentuation of the murmur is due to variation in the speed of flow with every pulse beat This could be studied during synchronous phonoarteriograms and ECG determinations Fig 4 shows a phonoarteriogram over a fistula (case 2) with a strong continous murmur In another case (case 4) the phonoarteriogram showed that the murmur was not fully continuous and instead was diphasic (Fig 5) In this case a strong high frequency murmur began late in systole then there was a clear pause before another murmur began in diastole The changes in the phonoarteriogram corresponded well with other methods recording changes in the circulation With calibrated phonoarteriography it is possible to register classify and compare the murmurs—even for purposes of teaching The murmur was propagated proximally and distally to the groin and to the knee

In two cases after the arteriovenous fistula the pulse rate was regularly somewhat higher than before operation No definite difference was established between the pulse rates after stage 1 and stage 2 There were insufficient observations in the other cases for an assessment of the pulse rates associated with 4 branched and 3 branched arteriovenous fistulae After the first half year a certain adaptation probably occurred With repeated examinations during the first few years after operation normal electrocardiograms and pulse rates were found

A definite reduction of the pulse rate by 6–10 beats per min was regularly obtained with compression of the fistula either manually or with a blood pressure cuff This sign which is usually called "*Branham s sign* in the textbooks is explained by reflex reduction of the heart rate with increasing of the peripheral resistance in the circulatory system

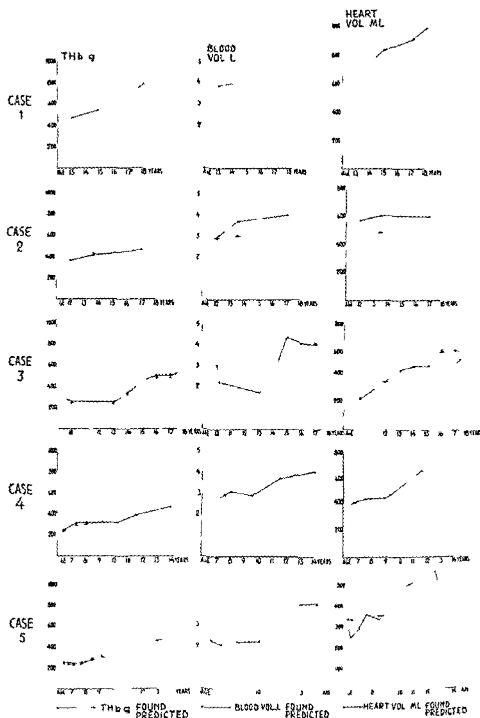


Fig 6

Survey of determinations of total amount of haemoglobin (THb) blood and heart volume after creation of an A-v fistula

CARDIAC SIZE, BLOOD VOLUME AND TOTAL HEMOGLOBIN

During the years following the creation of an arteriovenous fistula these patients had many examinations of their hearts, blood volumes and total hemoglobin. These were performed at the clinical physiology laboratory of the Karolinska sjukhuset.

Total amount of hemoglobin (THb). The THb was determined by the alveolar CO method, reported in 1948 by *Sjöstrand* (and with some minor modifications by *Carlsten et al.* 1954 and *Wiklander* 1956).

Blood volume. The total blood volume was calculated from the values for THb and the hemoglobinconcentration (Hb) determined from finger blood, disregarding the slight underestimation thus obtained due to the assumption that the hemoglobin concentration is constant in the whole blood volume. The normal value was calculated from the predicted THb 1.54.

The heart volume. The heart volume was determined in the prone position with two plane roentgenograms according to the method described by *Larsson & Kjellberg* 1948 and *Kjellberg et al.* 1951.

As shown by the curves in Fig. 6 the THb values in two patients (case 4 and 5) were somewhat lower than estimated. In the remaining three cases the values found were at the same level as expected. The blood volumes of all patients with the exception of case 5 lay at all times somewhat above the normal values. The same tendency was found in case 5 during the first years after the performed fistula. The hearts were slightly enlarged in four cases (case 1, 2, 4, 5). In case 3 the cardiac volume was judged as normal on every examination. Neither exceptionally high values nor any signs of progressive cardiac damage were found in any of the cases.

THE CONDITION OF THE VENOUS VALVES

Angiography studies were performed in all the cases.

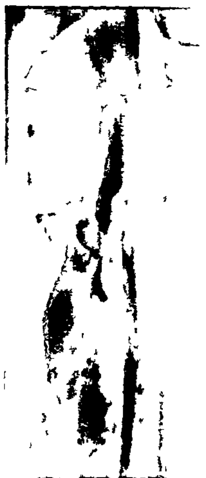
In 4 patients this was done in conjunction with stage 2 of the operation by injecting contrast material distally in the femoral vein.

The problems were 1) did the valves nearest the operation area constitute an absolute barrier to a distal flow in the femoral vein?

2) were there large venous branches near the fistula which too quickly directed the shunted arterial blood in a centripetal direction before it reached the growth zones in the knee region?

Even by arteriograms undertaken later[1] could these questions be

[1] These were performed in the Karolinska sjukhuset Radiology Department. In some occasions with stereo technique.



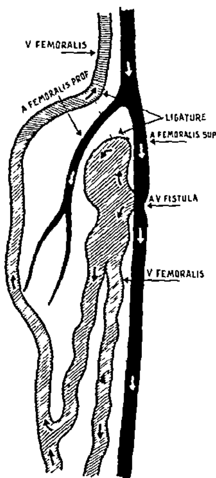


Fig 7

Arteriogram $5\frac{1}{4}$ years after creation of arterio venous three limbed fistula between the femoral artery and vein (Case 1) There is a large dilatation of the femoral vein For explanation see the schematic drawing compiled from several projections

answered in the negative and therefore an additional operative attack on the valves and the collateral veins was not required

Fig 7 shows a typical picture of the anastomoses area with the contrast medium filling the whole femoral artery and into the grossly dilated femoral vein distal to the ligature Some of the contrast rapidly passed proximally via superficial veins but a large part travelled *in the* distal direction

As shown in Fig 8 neither the venous valves nor the profuse collateral veins were able to divert the blood stream from the lower thigh



Fig 8
Arteriogram [illegible] years after creation of arteriovenous fistula (Case 5). There is a marked dilatation of the veins of the leg and increased vascularity around the knee.

TABLE II
Complications

Ca[illegible]	[illegible]	[illegible]
3	1950	Chronic ulcer 20 × 20 mm above the medial malleolus 1956–1958
4	1951	Chronic ulcer 20 × 20 mm of the calf 2 months 1955 Pulsating hemorrhage on one occasion Spontaneous thrombosis of the vein distal to the fistula 19[illegible]9 (beginning 1956) Local tenderness 2 months
5	19[illegible]1	*Chronic ulcer 25 × 25 mm above lateral malleolus*

and upper part of the foreleg A fairly large proportion of the contrast in this was reached the foreleg before the direction of the stream became centripetal The arteriograms showed in a convincing way the extremely *rich vascularization in the neighbourhood of the* growth zones in the knee region In the region of the fistula the femoral artery was somewhat narrowed but any significant pre or post stenotic dilatation of the artery was not seen

COMPLICATIONS

Chronic ulceration of the lower leg on the operated side appeared on three cases (see Table II) These were preceded by induration and tenderness and became fairly superficial sores of the type usually seen in chronic stasis They healed with rest applications of Burow s solution and elastic bandages but had a tendency to recur In one patient (case 4) a pulsating hemorrhage occurred on one occasion from the ulcer 2 cm *in diameter situated above the medial malleolus* The bleeding was arrested by compression The same patient later had a spontaneous venous thrombosis into the fistula

Dorsalis pedis and posterior tibial pulses could be demonstrated in all cases

THE GROWTH STIMULATING EFFECT

The clinical measurements with a tape measure and by wooden blocks under the short leg until the *pelvic obliquity was abolished* both showed a clear reduction of the leg length discrepancy during the observation time in all cases (see Figs 9–10 and Table III)

TABLE III

Case	Discrepancy in length of lower extremities in cm according to tape measurements		Duration of fistula	
	at creation of fistula	at closure of fistula	Years	Age of patient
1	7	2	5 3	12 18
2	9	2 5	6	11–17
3	5	[illegible]	[illegible] 5	9 17
4	5	2	6 or 7	6–13(14
5	5 5	1 5	7	6 13

Last follow up 1956 Unsuccessful tracing for follow up study 1960

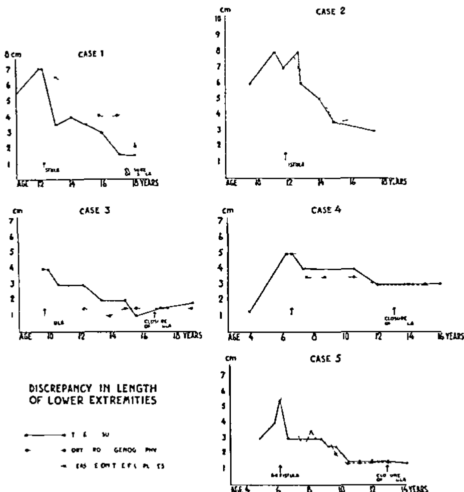


Fig 9

Result of growth stimulation by A-v fistula

The orthoroentgenographical method which has been used routinely in this clinic since 1953 and is described by *Sandaa* (1953) gives more exact values The figures from these later examinations ought not to be directly compared with those obtained by another roentgen measuring method which was used prior to 1953 This means that a completely satisfactory objective roentgen measurement of the growth stimulating effects produced by the arteriovenous fistulae is lacking in this study

If the effect is judged only by orthoroentgenography (since 1953) it is seen (Fig 9) that the leg length difference has been reduced in two

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Fig 10 A (Case 1)

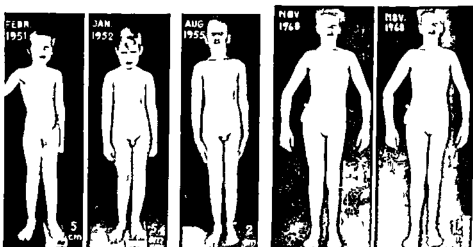


Fig 10 F (Case 4)

cases (case 1 and 5) Deviations of 0.5 cm and less are probably not significant According to the orthoroentgenographs the reduction in case 1 amounted to 2.5 cm and in case 5 to 1 cm during the time the fistula was open

Based on clinical measuring methods and partly on orthoroentgeno

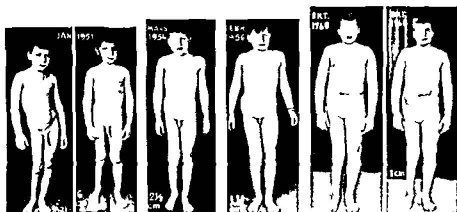


Fig 10 C (Case 5)

Fig 10
Photograms of patients operated on for discrepancy in length of lower extremities

graphic methods during a limited time a significant reduction of the leg length differences is demonstrated (Figs 9–10) This is interpreted as a growth stimulation of the short poliomyelitic extremities

CLOSURE OF THE ARTERIOVENOUS FISTULAE

Operative closure of the fistulae was undertaken in case 1 and case 3 at eighteen and seventeen years of age respectively The large venous sacs were ligated and the fistulae resected In case 1 a minor resection of the artery was performed because of thickening of the walls and luminal narrowing at the level of the fistula Arterial continuity was restored by end to end suture (see Fig 2 C 11 and 3) There was calcification in the walls of the fistula in case 3 and these changes prevented direct arterial suture after ligation of the venous sac Arterioplasty was withheld because of very good pulsating hemorrhage from the distal part of the artery and instead the artery was also ligated Oscillometry post operatively showed the previously hypernormal readings to be somewhat less than the readings on the non operated side The ulcerations on the calf healed

In case 2 the fistula was closed after 7 years when the patient was thirteen The reason for this somewhat too early closure was that the patient's parents were worried about the longstanding ulceration on the lateral malleolus (see Table III) The large venous sac was ligated and the arterial wall could be sutured and the patency retained After



Fig 11
Arteriogram after operative closure of fistula and arterial reconstruction (Case 1) For comparison see (Fig 7)

some months the artery became occluded over an area of about 10 cm The collateral circulation was however satisfactory the ulceration healed quickly Furthermore a subsequent triarticular subtalar arthrodesis healed without delay

Spontaneous closure by thrombosis of the femoral vein occurred in case 4 probably already after 6 years i e 1956 (see Fig 9) Angiography in 1959 and 1960 showed passage in the femoral artery but no longer an arteriovenous shunt

Case 2 lives in another country and could not be reached at the time of the last follow up examinations

Complications from the long term arterialization of the veins were not observed in any of the cases after closure of the fistulae No case of massive edema has occurred either during the time of function of the fistulae or afterwards

DISCUSSION

The number of operated cases has been limited to five in order to follow these carefully and study the effect and possible complications. The results of the larger series which have been operated in the Mayo Clinic and in Toronto are awaited with great interest. Regarding the technique for establishing the arteriovenous fistulae, the two-staged method developed by *Johnston et al.* 1950 seemed to be suitable.

The local effect of the arteriovenous fistula could be determined by simple clinical methods of examination. A loud "machinery" type of murmur and a clearly palpable thrill were demonstrable over the whole thigh, with the maximal point over the fistula. The veins in the thigh and foreleg became tense and pulsating and their contents lighter red. The pathophysiological condition was studied closer by a number of laboratory studies.

It was feared that the valves in the veins might offer such a resistance that the arterial blood would quickly turn in a centripetal direction. But this was shown not to be the case. An increased vascularization throughout the thigh and foreleg and into the knee epiphyses was confirmed by angiographic studies. In this connection may be mentioned that when congenital vascular abnormalities with arteriovenous communications are situated close to the growth zones, the risk of overgrowth of the affected extremity is greater (according to *Ward & Horton* 1940) than when the arteriovenous connections lie farther away.

The increased pressure in the veins in the vicinity of the fistula likely produced a certain degree of stasis. Artificial venous stasis has long been recognized as a growth stimulating factor and was employed most by *Bier* (1903) in the form of a tourniquet left in place for several hours a day in order to cause a temporary blockage of the venous return.

A general survey of other methods for producing local hyperemia in the vicinity of the growth zones can be found in "Surgical Treatment of Unequal Extremities" by *Coff* 1960.

The growth stimulating effect which is undoubtedly obtained after the construction of the arteriovenous fistula probably can be explained by 1) *increased circulation*, 2) *venous stasis* and 3) *constant increased temperature in the growth zones*. The obtained effect appears to be greater than by other hyperemic measures. The local complications have not been serious but in one case a prolonged ulceration over the lateral malleolus led to an earlier operative closure of the fistula than was

planned. Careful studies of the heart and blood volume during the time the arteriovenous fistulae were open showed no unfavourable effect.

Thus it seems that the method might be used in children with grossly retarded growth in one leg due to previous poliomyelitis. Careful twice yearly control of the blood and heart volumes, and the ECG, is desirable.

SUMMARY

Surgical construction of a 3 armed arteriovenous fistula between the femoral artery and vein has been used as a growth stimulating measure in 5 children between 6–12 years of age, who showed progressive leg length discrepancies.

The pathophysiological background and operative technique are described. The local and general effects of the arteriovenous fistula examined and recorded by different methods are discussed. After functioning for 5–7 years, the growth stimulating effects of the fistulae were obvious.

Minor complications in the form of ulcerations of the leg appeared but no adverse effect on the heart or blood circulation.

No venous insufficiency trouble appeared after closure of the fistulae and the distal chronic ulcerations healed.

RESUME

Formation chirurgicale d'une fistule arterio-veineuse de trois branches entre arteria et vena femoralis a ete utilise comme operation pour stimuler l'accroissement en cas de difference progressive des jambes a cinq enfants de l'age de 5–12 ans.

La base physio-pathologique et la technique de l'operation sont decrites. Les effets locaux et universels de la fistule arterio-veineuse enregistres et controles par des methodes differentes sont discutes.

Après 5–7 ans de fonction de la fistule l'effet stimulant sur l'accroissement etait manifeste. Des effets secondaires insignifiants en forme d'ulcerations au tibia se sont manifestes, par contre aucun effet defavorable sur le coeur ou la circulation.

ZUSAMMENFASSUNG

Die artifizielle dreiwegige arterio-venose Fistel zwischen arteria und vena femoralis wurde zur Stimulierung des Langenwachstumes an

funf Kindern im Alter von 5 bis 12 Jahren mit zunehmender Langen differenz der Beine angewandt

Der pathologisch physiologische Hintergrund und die Operations technik werden beschrieben Die mit verschiedenen Methoden regi strierten Lokal und Allgemeinreaktionen nach Anlegung der a v Fisteln werden diskutiert

5–7 Jahre funktionierende Fisteln gaben einen deutlichen stimu lierenden Effekt auf das Langenwachstum Geringfugige Neben wirkungen in Form von Ulcerationen an den Unterschenkeln kamen vor jedoch keine ungunstigen Nebenwirkungen auf Herz oder Blut zirkulation

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*FROM THE ORTHOPAEDIC HOSPITAL OF THE INVALID FOUNDATION
HELSINGFORS HEAD A LANGENSKIÖLD M D*

SPONDYLOLISTHESIS IN CHILDREN AND ADOLESCENTS

By

L I LAURENT and S EINOLA

The incidence of spondylolysis and spondylolisthesis in anatomically examined series is given at about 5 per cent (*Neugebauer Willis Roche & Rowe*) Radiographic examinations of the lumbar spine of adults gives an incidence of spondylolisthesis of 2 to 3 per cent (*Allen & Lindem Hult Runge*) The incidence does not seem to increase between the ages of twenty and seventy and after the age of twenty progression of the displacement appears to be exceptional (*Friberg Brocher Taillard* and others) Progression is not rare during the growth period however as was pointed out by *Friberg Francillon Brocher Taillard Laurent* among others The incidence of spondylolisthesis in the age groups eleven to twenty years is probably not any lower than the incidence in the older age groups (*Friberg Taillard*) Despite numerous investigations neither spondylolysis nor spondylolisthesis has been demonstrated in foetuses or newborn infants (*Batts Brocher Friberg Glorieux & Roederer* and others) The number of reported cases under ten years of age is insignificant amounting to some ten cases up to 1951 (*Marique*) This can probably be ascribed to the fact that at this age the lesion does not as a rule produce subjective symptoms nor does it result in any deformity of the spine and thus it escapes notice So far as we know radiological examinations of the lumbar spine of children for the purpose of investigating the frequency of spondylolisthesis have been carried out only by *Baker & McHollick* These authors examined 400 children aged six to seven years The incidence of spondylolisthesis was 4 5 per cent which is the same as in adults There is a hereditary predisposition to the lesion a fact which has also been demonstrated earlier (*Friberg Bakke Francillon George Wiltse Laurent* and others) Only two more extensive series of patients under twenty years of age with this lesion have been reported on (*Taillard Laurent*)

MATERIAL

During the 15 year period of 1944 to 1959 75 cases of spondylolysis and spondylolisthesis were observed at the Orthopaedic Hospital of the Invalid Foundation in patients under twenty years of age. Of these 58 cases have been briefly described in a previous report (*Laurent* 1958). The age and sex of the patients are given in Table I.

TABLE I
Age and sex on admission

Age	Boys	Girls	Total
0–4	–	2	2
5–9	6	1	7
10–15	13	14	27
16–19	24	15	39
	43	32	75

The sex distribution shows a slight preponderance of boys. In *Taillard's* series comprising 62 patients the incidence was the same for both sexes. Rather less than half the patients were under sixteen years of age, nine patients being under ten. The youngest patient was ten months old.

The age at the onset of symptoms is seen from Table II.

TABLE II
Age at onset of symptoms

Age	0–9	10–13	14–16	17–19	Total
No. of cases	12	21	33	9	75

In 33 cases symptoms first appeared when the patient was under 14 years of age (44 per cent). This would indicate a comparatively early onset. The location and nature of the lesion at the first examination are shown in Table III.

TABLE III
Location and kind of lesion on admission

	L4	L5	Total
Lysis	1	10	11
Olisthesis	4	60	64
	5	70	75

The lesion was located in the fifth lumbar vertebra in 93.4 per cent of cases and in the fourth lumbar vertebra in 6.6 per cent. Spondylolysis without displacement was demonstrated at the first examination in 14.7 per cent of cases. Unilateral lysis was present in 5 cases, the remaining cases exhibiting bilateral lysis.

Twelve patients ascribed their disorder to trauma of greater or lesser degree. In *Taillard's* series trauma occurred in 28 per cent of cases. Trauma is often the factor releasing the symptoms in spondylolisthesis. There is possibly a tearing of the fibrous tissue in the pars interarticularis of the vertebral arch leading to increased instability.

The frequency of various lesions in the lumbar spine occurring in conjunction with spondylolisthesis will be seen from Table IV.

TABLE IV
Associated lesions

Spina bifida	16 (23 %)
Sacralization	2
Transition vertebra	5
Trapezoid shape of the olisthetic vertebra	24
Upper anterior border of underlying vertebra rounded off	39
Osteochondrosis juvenilis of the spine	6

Spina bifida is often present in cases of spondylolisthesis. The incidence in *Taillard's* series was 42 per cent. In *Friberg's* series this incidence was 28 per cent, in *Meyerding's* 35 per cent. Juvenile osteochondrosis in lumbar vertebrae above the lesion occurred in three patients who were siblings and whose parents also had spondylolisthesis. This family has been described in a previous paper (*Laurent* 1958). In two patients there was a considerable deficiency of the anterior upper part of the vertebra below. A defect of so marked a degree is rare and may prompt a suspicion of an inflammatory or expansive process. Fig. 1 shows such a defect of the fifth lumbar vertebra in a 13-year-old boy with spondylolisthesis of the fourth lumbar vertebra. The fifth lumbar vertebra was sacralized. The patient underwent dorsal fusion and the operation revealed changes characteristic of spondylolisthesis in the dorsal portion of the fourth lumbar vertebra.

CLINICAL SYMPTOMS

A low degree of scoliosis occurred in 27 cases. In some cases the scoliosis was more pronounced and in these a rotation of the vertebra in the frontal plane could be observed in the frontal radiogram. In

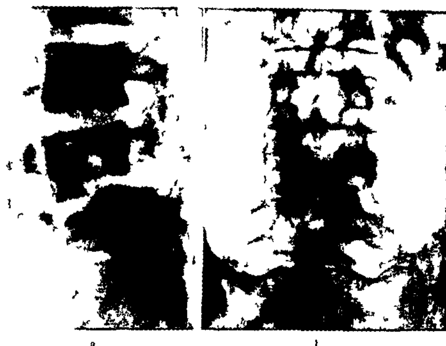


Fig. 4.
13 year old boy. Olisthesis of the fourth lumbar vertebra. The fifth lumbar vertebra is sacralized. Great defect of anterior upper border of the fifth lumbar vertebral body.

these cases unilateral spondylolysis, which according to *Glorieux & Roederer* predisposes to scoliosis, was not present. Rotation in the frontal plane may probably also take place solely as a result of the instability of the olisthetic vertebra.

While in adults pain in the lumbar region dominates the clinical picture in the majority of cases, *Taillard* reports that radiating pain in the lower extremities often occurs in adolescents with spondylolisthesis. The clinical picture in the present series is given in Table X.

TABLE X
Clinical picture in relation to age

	0-9	10-15	16-19	Total
No pain	5	4	2	11
Low back pain	4	13	21	38
Low back pain and radiating pain		10	16	26
Positive Lasegue's sign		10	10	20
Loss or diminution of ankle jerk		8	6	14
Sensory disturbances		1		1

Eleven patients were subjectively symptom free while 38 had pain in the lumbar region only. About one third of the patients had radiating pain, an incidence that tallies with that in adult patients (*Laurent* 1958). There were jerk disturbances in one fifth of cases. One patient exhibited a cauda equina syndrome with sensory disturbances and partial bladder paresis. This case has been described in a previous paper (*Laurent* 1958). The frequency of various disorders and deformities occurring in conjunction with spondylolisthesis will be seen from Table VI.

TABLE VI
Associated diseases and deformities

Post poliomyelitic sequelae	4
Tuberculosis of the spine	1
Idiopathic scoliosis	1
Spastic cerebral diplegia	1
Congenital dislocation of the hip	1
Talipes equinovarus	1
Other deformities of the feet	3
Perthes disease	1

PATIENTS UNDER TEN YEARS OF AGE

The age and sex of the patients are given in Table VII.

TABLE VII
Age and sex of patients under 10 years old

Age	Girl	Boy	Total
0–4	2	–	2
5–7	–	2	2
8–9	–	5	5
	2	7	9

The lesion was in all cases located in the fifth lumbar vertebra. The first examination revealed spondylolysis without displacement in four cases and slight displacement, which did not exceed one third of the vertebral length, in five cases. The spondylolysis was unilateral in three cases, two of which showed slight displacement. Seven patients were followed up ½ to 1 year later and the examination demonstrated that a slight displacement of 2 to 3 mm had taken place in two cases and a somewhat more marked displacement of 5 mm in one case. In



Fig. 9

10 month old girl with a congenital left club foot. Olisthesis of the fifth lumbar vertebra. The neural archs are hypoplastic; in the right arch there seems to be a defect. Spina bifida is present.

these cases there had been no displacement primarily In four cases no progression of the displacement was observed

The youngest patient was a ten month-old girl who was admitted to the hospital for left congenital club foot Radiographic examination of the lumbar spine showed unilateral spondylolysis and slight olisthesis of the fifth lumbar vertebra The affected neural archs were hypoplastic and spina bifida was present (Fig 2) Eight months later the condition was unchanged

The second youngest patient was 4½ years old and was admitted to hospital for spastic diplegia of the lower extremities present since birth A cesarean section had been performed because of transverse position A radiogram of the lumbar spine revealed bilateral spondylolysis *of the fifth lumbar vertebra which had slipped 3 mm forwards* (Fig 3)

Friberg had examined a ten month old girl with spondylolysis of all lumbar vertebrae The patient had numerous other congenital malformations such as dislocation of the hip club feet and subluxation of the knee and elbow joints In this case the spondylolyses were most probably also congenital It is possible that the spondylolisthesis in our youngest patient was likewise congenital The four year old girl had spastic paraparesis with characteristic spastic gait In this case a stress moment could be imagined which might have contributed to the occurrence of spondylolysis *Kleinberg* observed spondylolisthesis in a 17 month old girl with congenital dislocation of the hip Despite olisthesis comprising one half of the length of the vertebra no deformity of the lumbar back could be demonstrated clinically *Brailsford* observed spondylolisthesis in a three year-old patient and *Schmorl* found this lesion at autopsy in two children aged 2 to 2½ years

Our observations indicate that spondylolysis and spondylolisthesis are not rare among children aged 5 to 9 a fact which has also been demonstrated by *Baker & McHollick* in an extensive radiographic series of children 6 to 7 years of age It is generally a question of spondylolysis or a slight degree of olisthesis Since on the other hand spondylolisthesis has not been observed in newborn infants this would seem to indicate that spondylolysis occurs during the first few years of life possibly when the child begins to stand up and to walk and when the lumbar lordosis develops



Fig 3
4½ year old girl with cerebral spastic diplegia Olisthesis of the fifth lumbar vertebra and bilateral spondylolysis

OBSERVATIONS ON SLIPPING

The degree of slipping was measured as a percentage of the length of the olisthetic vertebral body (Fig. 4).

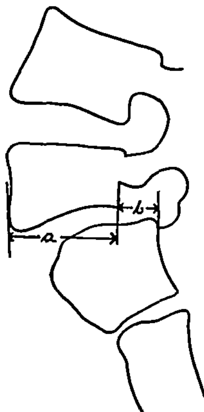


Fig. 4

$$\text{Slipping (per cent)} = \frac{b \times 100}{a}$$

The degree of slipping in relation to the age of the patient at the time of the first examination is shown in Table VIII.

There was spondylolysis or a slight degree of olisthesis in 44 cases (58.7 per cent). It seems as if the displacement often progresses in those cases in which it exceeds 30 per cent, gradually leading to subtotal or total olisthesis.

Of 75 patients 52 were followed up, the time of observation being 2 to 9 years. In the remaining 23 cases either the patient could not be followed up or else the period of observation was less than one year. Nineteen patients were operated on straightway, while 4 patients later

underwent operative treatment for progressive slipping. The frequency of progressive slipping is shown in Table IX.

TABLE VIII

Degree of slipping in relation to age on admission

	0-9	10-15	16-19	Total	
Lysis without slipping	4	1	6	11	14.7
Slipping less than 30 %	5	11	17	33	44.0
– 30–50 %		1	4	5	6.[illegible]
– 50–75 %	–	7	6	13	17.3
– subtotal or total	–	7	6	13	17.3
	9	27	39	[illegible]	100.0

TABLE IX

Progression of slipping in conservatively and operatively treated cases

	Progression	No progression	Not followed up	Total
Lysis (not operated)	4	4	3	11
Olisthesis (not operated)	13	14	18	45
Olisthesis (operated)	6	11	2	19
	23	29	23	[illegible]

Thus progression occurred in 23 out of 52 cases which could be followed up (44 per cent). There was progression in six operated cases. The frequency of progression of the slipping in the different age groups is shown in Table X.

TABLE X

Progression of slipping in relation to age

Age	Not operated	Operated	Total
0– 9	3	–	3
10–15	10	4	14
16–19	4	2	6
	17	6	23

Progression seems to take place most often at the age of 10 to 15 years. Since according to Table VIII a slipping exceeding 30 per cent often predisposes to further progression, operation should be considered at the age of 10 to 15 years if a displacement of over 30 per cent is present.

In spondylolisthesis of the fourth lumbar vertebra no high grade slipping could as a rule be established (*Laurent* 1958). Cases in which the fifth lumbar vertebra is sacralized constitute exceptions.

According to *Taillard* a trapezoid shape of the affected vertebra is a characteristic finding in spondylolisthesis. The dorsal height of the vertebra is less than its ventral height. This can be expressed by means of the so called lumbar index:

$$\text{Lumbar index L 5} = \frac{\text{Dorsal height of the vertebral body}}{\text{Ventral height of the vertebral body}} \times 100$$

Taillard examined the lumbar index of the fifth lumbar vertebra in 100 children without deformities, the average index being 89.5. In 50 cases of spondylolisthesis this index was 72. In the present series the index was likewise 72. The frequency of progression in relation to a lumbar index higher or lower than 70 in 52 followed up cases is shown in Table XI.

TABLE XI

Progression of slipping in relation to lumbar index

	Progression	No progression	Total
Index more than 70	14	14	28
Index less than 70	9	15	24
	23	29	52

It will be seen from the table that the lumbar index does not provide any reliable criterion for estimating the risk of progression of the slipping. In olisthesis below 30 per cent the index was as a rule higher than 70, whilst at a higher degree of slipping the index was often less than 70. This would seem to indicate that compression of the dorsal portion of the olisthetic vertebra is a secondary deformity arising when the slipping exceeds 30 per cent. However, in the present series the lumbar index was also lower than the average of normal subjects.

During the period of observation slight slipping occurred in four cases where there had primarily been no olisthesis. In seven out of nine cases with slight displacement the olisthesis progressed insignificantly without exceeding 30 per cent; there was considerable progression in two cases. In one out of three cases with olisthesis amounting to 50 to 70 per cent the olisthesis became total. In all six cases with subtotal olisthesis progression to total olisthesis took place. Thus considerable

progression of the displacement took place in 9 out of 52 cases (17.3 per cent).

According to *Taillard*, the shape of the ventral upper edge of the sacrum is a valuable guide to prognosis. If this edge is rounded off there is a risk of progression. The frequency of such changes in the present series is shown in Table XII.

TABLE XII

Changes in the underlying vertebra (anterior border rounded off) in relation to the grade of slipping

	Border normal	Border rounded off
Slipping less than 30 %	36	8
Slipping more than 30 %	–	31
	36	*39*

The table seems rather to indicate that the changes in the ventral edge of the underlying vertebra are secondary, occurring as a rule when the displacement exceeds 30 per cent. In exceptional cases a significant defect may be observed (Fig. 1).

TREATMENT

Of the 75 patients 52 (69.3 per cent) were treated conservatively while 23 (20.7 per cent) underwent surgery.

CONSERVATIVE TREATMENT

Of the conservatively treated patients 31 could be followed up, the period of observation being 2 to 9 years. Sixteen patients could not be followed up and in five cases the period of observation was less than one year. In these 21 cases the treatment consisted of a cloth corset in eight cases and of physical therapy in three cases, while in ten cases no treatment was considered necessary. In the 31 followed up cases the treatment was as follows:

No treatment	5
Physical therapy	15
Surgical corset	11
	31

The functional results of treatment were divided into three groups as follows

Group I No pain
Group II Slight low back pain occasionally
Group III Low back pain and radiating pain frequently

The results of the conservative treatment are shown in Table XIII

TABLE XIII
Functional results of conservative treatment

	Group I	Group II	Group III	Total
No treatment	3	2	–	5
Physical therapy	5	8	2	15
Surgical corset	1	3	7	11
	9	13	9	31

Despite corset and physical therapy backache and radiating pain persisted in nine out of 31 cases The symptoms were not so marked however as to constitute indications for operation Three of these patients were remitted to a vocational school for the disabled During the period of observation the degree of olisthesis remained unchanged in 18 cases while in 10 cases an insignificant progression of 1 to 15 per cent occurred Considerable progression had taken place in three cases subtotal olisthesis progressing to total in two of these These patients probably should have been operated on even though it would have been uncertain whether progression could have been arrested by this measure

OPERATIVE TREATMENT

Twenty three patients underwent operative treatment The indications for operative treatment were as follows

Low back pain	2 cases
Low back pain and radiating pain	15 cases
Risk of progression and displacement	6 cases
	23 cases

The operations carried out were as follows

Reduction and dorsal fusion	1
Dorsal fusion	14
Dorsal fusion with exploration or laminectomy	4
Ventral fusion	2
Laminectomy alone	2
No operation	3

At dorsal fusion a tibial graft was, as a rule, applied and during recent years two grafts and cancellous bone from the upper end of the tibia. The intervertebral joints were left intact. The patients were confined to bed for six weeks after operation and were then given plaster jackets for 2 to 3 months. Of the 19 cases of dorsal fusion 15 could be followed up, the period of observation being 2 to 10 years, 5 years on average. The period of observation was less than one year in four cases.

In one case reduction according to *Watson Jones's* method was attempted. The patient was twelve years old and had spondylolisthesis of the fifth lumbar vertebra of 22 mm (78 per cent). At reduction the displacement was reduced by 5 mm, but this was lost again and a control radiogram six weeks after dorsal fusion showed the same degree of slipping as before operation. In *Taillard's* series considerable reduction of the displacement was obtained in seven cases, but in only one case could the reduction be maintained by dorsal fusion.

The functional results in fifteen cases in which dorsal fusion was carried out were as follows:

Group I	5
Group II	5
Group III	5

In the last group three patients were reoperated on. In two cases exploration was carried out for recurrence of radiating pain and one patient was operated on for persisting backache. In two of these cases pseudarthrosis of the graft was present. Two of the patients were symptom free after reoperation, while one had slight symptoms periodically. Control examination showed that in eleven cases the displacement was unchanged after operation, while progression had taken place in four cases despite good consolidation of the graft. Fig. 5 shows such a case.

Consolidation of the graft was achieved in twelve cases, two of which, however, exhibited pseudarthrosis above the area involved. Here the graft was unnecessarily long. In two cases in which there was pseudarthrosis of the graft, reoperation was carried out. Consolidation was uncertain in one case.



Fig 5

15 year old boy Subtotal olisthesis of the fifth lumbar vertebra Dorsal fusion with bilateral paraspinal grafts was performed six weeks earlier Two years later the slipping has progres ed and is now total The grafts are slightl bent

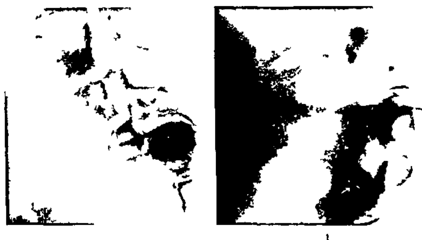


Fig 6

14 ear old b y Subtotal oli thesis of the fifth lumbar vertebra Ventral fusi n with an iliac graft was perf rme l F ur years later the olisthesis is total There is p eud arthro is between the graft and the sacrum

Satisfactory functional results were thus achieved in thirteen out of fifteen cases by means of dorsal fusion and after three reoperations had been carried out Despite dorsal fusion progression could not be prevented in four cases In three of these subtotal olisthesis progressed to total olisthesis Here ventral fusion might possibly have prevented progression

The results seem to indicate that olisthesis in adolescents should be operated on before it becomes subtotal. When the displacement begins to exceed 30 per cent operation should be considered and should further progression occur operation is indicated. In most of these cases progression can be arrested by dorsal fusion.

Ventral transperitoneal fusion was carried out in two cases in which the patients were under 20. The body of the fifth lumbar vertebra was fused with the first sacral vertebra by means of an iliac graft. There were no operative complications. Consolidation was achieved in one case, the patient being symptom free at follow up examination. The olisthesis, which was primarily 90 per cent, was unchanged. In the second case pseudarthrosis occurred and the displacement increased during the period of observation from 77 per cent to total (Fig. 6).

The symptoms were alleviated after operation but there was slight low back pain periodically. The patient was remitted to a vocational school for the disabled.

Laminectomy without fusion was carried out in two cases. One patient had a cauda equina syndrome and total olisthesis of the fifth lumbar vertebra. After operation the backache and bladder disturbance were relieved, the other neurological symptoms, which have been described earlier (*Laurent* 1958), persisting unchanged. The other patient was a 17 year old girl on whom laminectomy was carried out for sciatica. Although the radiating pain was somewhat alleviated after operation, the backache persisted unchanged. At follow up the displacement, which was 90 per cent, remained unchanged. In this case a console had developed at the ventral upper edge of the sacrum and this console had evidently prevented further progression. Such console formation is common in adult individuals with spondylolisthesis but seldom takes place in patients under the age of 20.

In our opinion in young individuals with spondylolisthesis laminectomy without simultaneous fusion should only be carried out on special indications.

The functional results after operative treatment in 19 followed up cases are shown in Table XIV.

Backache and radiating pain which are not affected by conservative treatment constitute operative indications. As a rule conservative treatment should first be attempted. Patients with a displacement exceeding 30 per cent of the length of the vertebral body should be carefully followed up and further progression should be prevented by operation. Dorsal fusion results in satisfactory relief of pain but cannot

always arrest progression of the displacement. In subtotal olisthesis progression to total olisthesis cannot, as a rule, be prevented by dorsal fusion. Ventral fusion might give better results but there is a risk of complications after this operation. In our opinion dorsal fusion should be carried out before the olisthesis has become subtotal. Reduction may occasionally succeed, but the results of reduction are difficult to maintain.

TABLE XIV

Functional results of operative treatment

	Group I	Group II	Group III	Total
Dorsal fusion (3 reoperations)	7	6	2	15
Ventral fusion	1	1	–	2
Laminectomy	–	–	2	2
	8	7	4	19

CONCLUSIONS

A study of 75 cases of spondylolysis and spondylolisthesis in children and adolescents gave rise to the following conclusions.

1. This lesion is not uncommon in children under ten years old. At this age there is generally only a slight degree of displacement, if any, and subjective symptoms are often altogether absent. The lesion therefore mostly eludes diagnosis at this age. Spondylolysis probably occurs during the first few years of life.

2. Progression of the displacement is common in children and adolescents. Progression was observed in 23 out of 52 followed up cases (44 per cent). Progression seems most frequently to take place between the ages of 10 to 15. At the first examination spondylolysis without slipping was present in 14.7 per cent of cases, and in 44 per cent the slipping was less than 30 per cent of the vertebral length. The slipping was 30 to 75 per cent in 24 per cent of cases, subtotal or total olisthesis being present in 17.3 per cent of cases. Subtotal olisthesis as a rule progresses to total olisthesis despite dorsal fusion.

3. Sciatica was present in one third of cases.

4. A trapezoid shape of the olisthetic vertebra and rounding off of the anterior edge of the underlying vertebra are often observed. Our material indicates that these changes are secondary, occurring when the olisthesis exceeds 30 per cent. The lumbar index does not provide a safe basis for the estimation of the risk of progression. If the displace

ment exceeds 30 per cent it often progresses further towards a more severe degree of olisthesis

5 Dorsal fusion provides good results in cases in which conservative treatment does not relieve the pain As a rule dorsal fusion cannot prevent progression from subtotal to total olisthesis In such cases ventral spondylodesis may afford better results If the displacement amounts to 30 per cent the patient should be kept under close observation and dorsal fusion should be carried out when there are signs of progression and before the displacement has become subtotal Reduction may succeed but it is difficult to maintain

SUMMARY

During the period 1944 to 1959 75 cases of spondylolysis or spondylolisthesis in children and adolescents were observed Nine patients were under ten years old the youngest being ten months 52 patients were followed up the period of observation being 2 to 10 years Progression of the displacement occurred in 23 cases (44 per cent) Sciatica was reported in one third of cases Little displacement if any occurred in 58 7 per cent of cases and a higher degree of olisthesis in 41 3 per cent Progression most frequently took place at the age 10 to 15 years If the displacement exceeded 30 per cent further progression usually took place Subtotal olisthesis as a rule became total even despite dorsal fusion Dorsal fusion tended to relieve the pain If the displacement amounts to 30 per cent of the vertebral length the patient should be kept under close observation and if there are signs of progression dorsal fusion should be carried out before the displacement has become subtotal If there is subtotal olisthesis ventral fusion may prevent further slipping

RESUME

Durant la periode 1954 a 1959 75 cas de spondylolyse ou de spondylolisthese chez les enfants et les adolescents ont ete etudies Neuf malades avaient moins de 10 ans le plus jeune n avait que 10 mois 52 malades ont ete suivis pendant une periode d observation entre 2 et 10 ans Une progression du glissement a ete constatee dans 23 cas (44 %) Des sciatiques ont ete rapportees pour un tiers des cas Un leger deplacement a ete observe dans 58 7 % des cas et un plus haut degre d olisthese dans 41 3 % La progression prend frequemment place entre 10 et 15 ans Si le deplacement depasse 30 % il se produit generalement

une nouvelle progression Une olisthese subtotale devient en regle generale totale meme en depit d une fusion dorsale

La fusion dorsale tend a soulager des douleurs Si le deplacement s eleve a 30 % de la longueur de la vertebre le malade doit etre tenu sous observation et s il y a des signes de progression une fusion dorsale doit etre pratiquee avant que le deplacement ne devienne subtotal S il y a olisthese subtotale une fusion ventrale peut empecher un glissement ulterieur

ZUSAMMENFASSUNG

Wahrend des Zeitraumes 1944 bis 1959 wurden 75 Fälle von Spondylolysis oder Spondylolysthesis bei Kindern oder Jugendlichen untersucht Neun Patienten waren unter zehn Jahre alt Der jungste von ihnen war zehn Monate alt 52 Patienten wurden nachuntersucht Der Beobachtungszeitraum erstreckte sich von 2 zu 10 Jahren Ein Fortschreiten der Verschiebung trat in 23 Fällen (44 %) auf Ischias wurde in einem Drittel der Falle berichtet Eine kleine wenn überhaupt eine Verschiebung trat in 58 7 % und ein hoherer Grad von Olisthesis in 41 3 % der Fälle auf Die Zunahme der Verschiebung geschah am haufigsten im Alter von zehn zu funfzehn Jahren Wenn die Verschiebung mehr als 30 % uberstieg kam es in der Regel zu einem weiteren Fortschreiten Subtotal Olisthesis bekam in der Regel total selbst trotz dorsaler Fusion

Die dorsale Fusion erleichterte gewohnlich die Schmerzen Wenn die Verschiebung 30 % der Wirbellänge beträgt sollte der Patient unter genauer Beobachtung gehalten werden und wenn Zeichen des Weitergleitens auftreten sollte die dorsale Fusion vorgenommen werden ehe die Verschiebung eine subtotale geworden ist Wenn eine subtotale Verschiebung bereits vorhanden ist kann eine ventrale Fusion weiteres Abgleiten verhindern

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FROM THE CHILDREN'S HOSPITAL ORTHOPAEDIC CLINIC, ATHENS, GREECE
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NEW CONCEPTIONS CONCERNING THE TREATMENT OF ACUTE OSTEOMYELITIS IN CONSIDERATION OF THE PATHOLOGICAL FINDINGS AND THE ACQUIRED RESISTANCE OF STAPHYLOCOCCI IN CONNECTION WITH ANTIBIOTICS

By

J. MICHAIL, K. HOLLIARAS, S. THEODOROU, N. STATIS
and K. SPYROPOULOS

The general use of antibiotics in the treatment of acute osteomyelitis has reduced the relapse rate as well as the previously high mortality to a negligible quantity. In a pre-war statistical study at the Toronto Sick Children's Hospital there was a 20 % mortality among 670 cases of acute osteomyelitis (*Farmer* (1), 1948). In our own recent series there has been no death among the 155 children treated during the last 6 years.

Nevertheless, the reduction of the complications in acute osteomyelitis has not paralleled the lessening in the mortality. This is mainly due to the fact that in the treatment of the disease insufficient attention has been paid to the pathological changes and the development of the new resistant strains of staphylococci. The recent basic work on the subject (*Trueta* (2, 3, 4, 5) *and coll.*) suggests that the pathological lesion is usually a thrombosis involving the bone and producing bone necrosis.

There have been many attempts to describe the pathogenesis of acute osteomyelitis. The best descriptions are given in the classical works of *Lannelongue* (6) (1879) and *Trueta* (1953). With slight differences, they admit the initial localization of the infection deep in the bone matrix spreading gradually to the cortex. Bone necrosis is a usual consequence of the ischemia. Some other authors among which are *Lexer* (7), *Crile* (8), *Leveuf et coll.* (9, 10, 11, 12, 13) believe that the initial localization

is found around the point of penetration of the cortex by the nutrient artery. The principal lesion is a thrombosis of the artery which gives rise to a necrosis of the bone extending from the cortex to the medulla. Our feelings are in keeping with the *Lanelong's* classical conception.

After a detailed study of the question we consider that the pathogenesis of the disease goes through the following stages: after the staphylococcus has entered the circulation of the bone it shows a predilection for those regions where the circulation is slowest. Such is the metaphysis of the long bones *especially after trauma. Lewis* (14) (1956) has shown that the blood supply of the long bones comes partly from the nutrient artery and partly from the periosteal vessels. This periosteal circulation increases as the person grows older for then the bone is essentially supplied by this periosteal circulation. The numerous venous sinuses in the metaphysis slow the local circulation and in this way favour the development of the staphylococcal abscess.

As a consequence of the bone necrosis a local inflammatory reaction is set up which leads to the development of a bone abscess. The pus spreads into the medulla and through the cortical channels to form a subperiosteal abscess. Since these bone constituents have their own arterial branches the direct hematogenous infection of the periosteum (periostitis) and of the cavum medullae is possible though not frequent. Pus collection tends to the enlargement of the necrotic areas. The rupture of the periosteum under growing tension is a dramatic development that may be avoided. We emphasize the great importance of the above pathological changes because we consider that the failure to understand this leads to insufficient or erroneous treatment. This loses precious time during which it would have been possible to avoid more extensive necrosis of the bone with the distressing sequelae outlined below.

1. large abscesses with one or more fistulae
2. very large bone necrosis (pandiaphysitis) which may result in pseudarthrosis
3. ankylosis of one or more joints. More frequently stiffness
4. differential growth ending in anisoskelia
5. in some rare cases an amputation may be the dread result

The tratment of all these complications necessitates a long period of medical control often with serious financial and physical consequences. Consideration of these principles led us to institute the method of treatment outlined below in a series of 45 cases of acute osteomyelitis



a b

Fig 1

a B The 1 r bov aged 3 An example of metaphyseal localization Admitted after failure f conservative treatment

b No doubt that he was late for suitable surgical treatment The consequence was a pandiaph siti Progn i will be in pite of this g d but durable



a b c

Fig

a The risk i gre ter in this case concerning K Artemi a girl aged 4 She as a lmitte l after pr l nged c nservative treatment with exten led n cro i inclu l ing the liaph i a a wh l

b Fracture and sh rtening en ue l

c Many pla ter will l nece ary bef r we c n h pe to r m v fragm nts f the c ncell u b ne Tr atment will la t month an l e en year



Fig. 3

a. C. Constantinos, aged 11. He was sent for operation after a very long period of conservative treatment. We noticed on admission a large necrosis either of the bone or of the skin.

b. A large involucrum was taken out from the ulcerated skin. We had to wait a few months until grafting was possible. Series of plasters were necessary.

Altogether 155 cases of osteomyelitis were treated but 110 of the patients had the chronic form of the disease. We have not included them in this work as they have been the object of a previous paper already published (*Michail and coll.* (15) 1951).

As the principle object of this paper is then the study of the acute osteomyelitis, our remarks are related to the 45 acute cases. These patients were admitted into the Orthopaedic Clinic between 4 and 30 days from the onset of the disease. Almost all these patients had been treated elsewhere before their admission by antibiotics. So in the majority of the admitted cases we had to face the development of resistant strains. Because of this and the established bone necrosis our end results were not as satisfactory as we could hope when starting to treat our patients by the following method.



c d

Fig 3

c The b ne aut graft wa well incorporated

d N w 3 ear later the graft is thick en ugh s the patient i all we l t walk with me precauti n



a b c

Fig 4

a N all b n d tructi n h n thi b w l C rgi ag d f when admitted

b But r n a b ne de tructi n became evi t nt with l f b n ul t nce

Grafting n ue l ith perf ct re tituti n



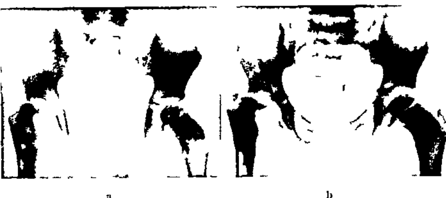
Fig 5

a. I. Dimitrios, aged 3. Early opening and fenestration of the bone. Evacuation of the subperiosteal and bone abscess.
b. Excellent result. Healing without any late complication. It is clear that no conservative treatment was carried out.

As soon as a localization is perceptible, we open the soft tissues down to the periosteum. Hence we can drill the bone cortex. But this seemed to us insufficient, so we prefer now the fenestration of the bone either at one or at both epiphyses simultaneously. Before doing this as a routine procedure we missed a second localization in two cases. We usually insert a drain before closing the soft tissues. Local and general antibiotherapy is continued for about 3 weeks after checking the sensibility of the staphylococci. In local antibiotherapy we manage so that the drug is entirely introduced into the bone medulla through the cortical window.

Allthough the same procedure was carried out in all our cases, it was *sometimes impossible to stop the bone necrosis*, because this was already established before operative treatment began. It is important to realize that no radiological findings can be made before the third week (*Brailsford* (16)). It is therefore important to undertake the operative treatment in consideration of clinical symptoms without waiting for *the* appearance of radiological findings.

The picture of the evolution of acute osteomyelitis varies with the patient's age. The younger the child, the more severe is the disease. Osteomyelitis is most frequent in children between 7 and 10 years old



a b

Fig C

a *J Satiris aged 3 Admitted after a long conservative treatment Puncture of* the abscess followed by injections of penicillin The result was the absorption of the head

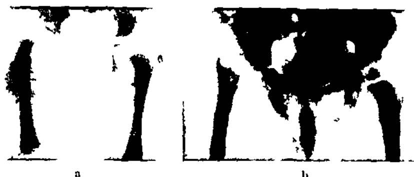
b After opening the hip joint and immobilization for a long time the result was good enough so we could hope to conserve movement and acceptable bearing

Among our 155 cases 50 are aged between 7 and 10 Males are more frequently affected than females Localizations of the disease are divided according to their types as follows 69 femurs 51 tibiae 14 humeri 10 fibulae and 11 rare localizations These figures appear from our own statistics But they are somewhat different from those of *Trueta Key* (17) and others who found the tibial localization to be the most frequent one The original source of infection is not as easy to discover as it may seem We omit therefore to insert any statistical figure The most frequent localizing factor may be a trauma as we found this to be true in 45 among our 155 cases

As a matter of observation we believe that the staphylococcic infection goes through the following stages a) primary infection (skin nose pharynx ear) b) hematogenic septic infection with phlegmon and c) tertiary phase which results in multiple thrombosis causing osteomyelitis When this last is attained we may expect to have a *relative immunity*

In order to know something more about the infective agent we performed systematic laboratory examinations of the pus In 45 acute cases examined we found staphylococcus 42 times and streptococcus 2 times proteus was the infective agent of only one case

Staphylococcus aureus and micrococcus pyogenes proved to be the most resistant to antibiotherapy infective agents *Margel* and *Richar*



a b

Fig 7

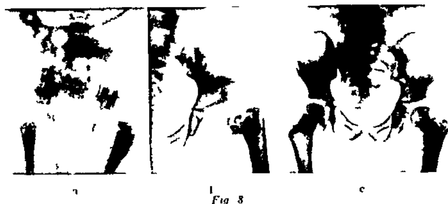
a S Johannis 3 months old Conservative treatment lasted longer than in the preceding case so the absorption of the head and neck was total with luxation
b We hope to do something to improve this disastrous condition But the boy is still too young

(18) (1955) tried to explain the way these agents proceed by means of toxines and enzymes Toxins are a) an exotoxin which has a necrotic and hemolytic power b) a leucocydin which destroys the leucocytes and c) an enterotoxin which is rather a poison when ingested Enzymes are a) coagulase and b) a fibrolysin both are comparative to the hyaluronidase (spreading factor) Penicillin was found to be inactive from the beginning of the treatment in 21 acute cases In 21 other cases penicillin activity was moderate at first then quickly diminished The most active antibiotics were chloramphenicol erythromycin sigmamycin terramycin novobiocin and kanamycin but each one became less effective with the lapse of time In three cases resistance was noted after short use Streptomycin seemed to have a resistance resembling that of penicillin (*Rauntree* and *Thomson* (19) *Linzenmayer* (20) *Arsenis* (21))

To consider the respective value of our therapeutic results our cases were divided in two groups The time which preceded the admission of each patient after they had been infected was taken into account

Group I

This group comprises 21 acute cases admitted after they had been treated elsewhere during a period of time varying between 5 and 10 days The treatment already given had been inadequate In exceptional cases no treatment had been given Penicillin or streptomycin was usually administered without any control In all these cases the current



a b c

Fig 8

a T Constantinos 1 month This infant came as soon as the physician realized that there was very little hope of improving the condition by conservative treatment On the x ray partial destruction and luxation is evident

b After opening and treating the local condition we noticed encouraging improvement But immobilization was very long

c The result was indeed good 4 years later after a successful high osteotomy

operative treatment was indispensable and pressing abundant pus was found inside the periosteum and in the bone matrix In half of these cases the amount of pus was so great that it had spread into the soft tissues Suitable postoperative antibiotherapy was given after a resistance control had been carried out The results of this combined operative and medicamental therapy are as follows

In every case a striking improvement of the general condition of the patient was noticed Temperature became normal 2 to 3 days after the operation The sedimentation rate became gradually normal But no parallel improvement was noticed on X rays This became evident in after weeks

After the 4th week one could notice an important improvement of the local situation in 14 among the 21 acute cases of this group But the X rays still showed a few changes In the other 7 cases repair of the bone was retarded 3 of them were even more difficult to heal because of the wide spread of the infection and difficulty in obtaining adequate drainage In similar cases we now prefer to open a window in the cortex of both epiphyses and more widely than before

Group II

This includes the remaining 24 acute cases admitted after the 10th day Longer antibiotherapy without any control This is the consequence



a b c

Fig 9

a B Dimitra 3 years old She came with a partial destruction of the whole femur after a very long conservative treatment

b After surgical treatment it has only been possible to conserve the diaphysis with the inferior epiphysis The upper epiphysis was completely absorbed and a luxation ensued

c The result was very satisfactory 2 years later after a difficult osteoarthroplasty

of a fundamentally wrong conception that one can surely heal a sub acute osteomyelitis in using antibiotics for a long period So they believe in discarding operative treatment It then follows from this that the end results in this group are ordinarily disastrous

In only 2 of these cases could the results be compared with those in the preceding group in spite of their late admission (20 days since the beginning of the disease) a satisfactory result was obtained But we had to evacuate a large collection of pus

We had to face on the other hand a very serious situation in the following 2 cases The persistence of the conservative treatment over a month caused the rupture of the subperiosteal abscess the pus over flowed in the soft tissues A large skin necrosis was noticed as well as a large bone necrosis A huge sequestrum had to be removed leaving an extensive gap (pseudarthrosis) Five more cases were admitted in our Clinic with a dislocation of the femoral shaft because of the unjustified prolongation of the conservative therapy in cases of purulent arthritis of the hip Parents were disheartened when informed of a certain *degree* of permanent disability These patients having no fever no pain and no swelling after a more or less long conservative treatment were supposed to be cured and therefore allowed to walk without any *support* or control

It is then evident that the improper administration of antibiotics may

not only be ineffective but also be dangerous Despite this some author among them *Endler* (22) (1957) prefer aspirating and instilling a scesses They persist in continuing conservative treatment until bo necrosis becomes obvious This takes ordinarily a long time because an illusive improvement Inevitably these patients come in after wee or months for operation In such cases—those of group II—the e results will be unfortunate The bone lesions are of such exte (usually pandiaphysitis) that it is necessary to wait several mont until a sheath of new bone is formed before one can operate If we not wait long enough we are apt to produce a pseudarthrosis As happens very often more than one operation will be necessary It is n always a simple thing to remove the diaphysis when necrosed A fra ment is very often ready to be removed before the whole is separate

Acute osteomyelitis of the infant is to be considered separately b cause of the fast evolution of the phlegmon Almost all of our patier showed a localization at the hip joint So we are prone to consid this as the most frequently affected joint Damage is usually gr When diaphysis was reached we found the spreading or the pus in so tissues to be in the infant less frequent than in children The gre elasticity of the periosteum at this early age favours the subperiost pus collection (*Blanche* (23))

Among our 8 infant cases with acute osteomyelitis 6 had an absce of the hip joint 1 of the femur and 1 of the humerus In 3 of the cases where the hip was affected the head of the femur was absorb But in one of these cases the head was partly absorbed because noted a regeneration of it 3 years later In the remaining 3 cases w in early operation in our Clinic the final result was good The res was the same with the femur and humerus acute osteomyelitis absce

As a rule patients with purulent arthritis are brought to us very la The results could be better and in a shorter time This is to be put do in certain cases to the many diagnostic difficulties and errors Sym toms may be lacking or may become manifest only after abscess f mation For this reason the X ray examination is valuable A s luxation of the femoral head will be a frequent and in most instanc a very early radiological finding When this is observed it is necess to evacuate the pus in an emergency arthrotomy By doing this one expect to avoid the necrosis of the head Local and general antib therapy will be useful provided that the affected limb be kept immobility

CONCLUSIONS

Acute osteomyelitis though now less frequent and less dramatic than before the antibiotherapy time is nevertheless a serious and longlasting disease. All ages are affected but children more frequently, males more than females.

The principal agent is staphylococcus (we found this in 42 among 45 pus cultures). Metaphysis is in children the commonest localization. Trauma is an important fixative factor.

Conservative therapy when carried out during the period of bacteriemia may end in a complete arrest of the disease. But it has little likelihood of a cure when localization is established. Taking into account the fact that in very few cases intensive and effective treatment is practicable in the septicemic period we are prone to admit its inefficacy in the greater number of acute osteomyelitis. In many instances it serves to produce new resistant strains. *Sal.* (24) reviewing 101 cases of acute hematogenous osteomyelitis came to the same conclusion.

The early operation is undoubtly the treatment of choice in all cases in which a localization is evident. The earlier this treatment is carried out the better the result will be and in the shortest time. This average time is about 2 months in our cases of group I. It takes months for the cases of group II and years for some chronic patients. Our routine technique is based upon the very many pathological verifications that we have performed these recent years. If we are convinced of the existence of a central bone abscess in the presence of a phlegmon with bony inflammation we look for it at one or both epiphyses. As early as possible, mostly before the appearance of the slightest radiological sign, we open the bone cortex as well as the soft tissues even though a large abscess is amassed inside or outside the periosteum. The doubtful efficacy of the drilling of the cortex urged us to go on with the fenestration of the cortex. The fact that in the infant the condition causes a severe and often permanent epiphyseal damage and joint infection *Trueta* (25) makes incontestable the very early opening of a purulent joint.

The testing of the resistance was undertaken in all our acute cases in which staphylococcus was in the limelight. Penicillin is of little or no value, streptomycin scarcely effective. We recommend as among the most effective therapeutic agents chloramphenicol, erythromycin, sigmamycin, terramycin, novobiocin and kanamycin.

SUMMARY

Remarks and results concerning the study of 155 osteomyelitic children, among which 45 were acute cases treated for several weeks or months in the Children's Orthopaedic Clinic of Athens, are reported. The main problem discussed is that of the treatment of acute osteomyelitis.

It appears from this study that conservative antibiotherapy, when continued for a long time—after the development of a phlegmon, is of little or no value and in many instances increases the risks of an infirmity.

Combined with a methodical and rational antibiotherapy, our routine technique is more effective. This operative procedure is described including our personal modification. With this surgical treatment good results were obtained in 66 % of the acute cases of group I. Satisfactory results were obtained in only 8 % of the cases of group II. The patients of this group II were mostly following—before their admission—a conservative treatment for a long period until an extensive bony destruction became obvious and therefore difficult to heal.

RÉSUMÉ

Les auteurs font connaître leurs observations et résultats thérapeutiques après étude de 155 dossiers d'enfants atteints d'ostéomyélite, parmi lesquels 45 sont des cas aigus. Ces malades ont été en traitement chirurgical dans la clinique de Chirurgie Orthopédique de l'Hôpital des Enfants d'Athènes durant quelques semaines ou quelques mois. C'est le problème thérapeutique de l'ostéomyélite aiguë qui a retenu spécialement l'attention des auteurs.

Il ressort de cette étude que le traitement conservateur par les antibiotiques, *s'il est continué longtemps après la formation d'un phlegmon*, non seulement est sans utilité, mais au contraire accroît les risques d'infirmité.

L'opération combinée à un traitement conservateur (par antibiotiques) systématique et rationnel est plus efficace. Nous donnons un compte rendu de la technique opératoire que nous utilisons en y ajoutant notre contribution personnelle. Par ce traitement chirurgical nous avons enregistré de bons résultats dans 66 % des cas en ce qui concerne le groupe I. Dans le groupe II il n'y a eu de bons résultats que dans 8 % seulement des cas. Les malades de ce dernier groupe ont été soumis

pendant un temps plus ou moins long — avant leur admission dans notre Clinique — à un traitement conservateur pur et simple jusqu'au moment où une destruction importante de l'os est devenue manifeste et par conséquent très difficile à guérir

ZUSAMMENFASSUNG

Beobachtungen und Ergebnisse im Zusammenhang mit der Untersuchung von 155 an Osteomyelitis erkrankten Kindern unter ihnen 45 akute Fälle die während einiger Wochen oder Monate in der orthopedischen Kinderklinik von Athen behandelt wurden werden berichtet Das hier besprochene Hauptproblem ist das der akuten Osteomyelitis

Aus dieser Untersuchung geht hervor dass die konservative Behandlung mit Antibiotika wenn eine lange Zeit hindurch fortgesetzt — nach der Entwicklung einer Phlegmone nur geringen oder gar keinen Wert hat und dass sie in vielen Fällen die Gefahr eines dauernden Gebrechens erhöht

Zusammen mit einer grundlichen und rationellen Antibiotikabehandlung ist unsere Routinetechnik wirkungsvoller Das operative Vorgehen mit unserer persönlichen Modifikation wird erläutert Mittels dieser kirurgischen Behandlung wurden gute Ergebnisse in 66 % der akuten Fälle der Gruppe I erzielt Zufriedenstellende Ergebnisse wurden in nur 8 % *der Fälle der Gruppe II* erhalten Die Patienten dieser Gruppe II hatten meistens eine langdauernde konservative Behandlung vor der Aufnahme ins Krankenhaus mitgemacht während der es zu ausgedehnter Knochenzerstörung gekommen war und die deshalb offensichtlich schwierig zu heilen waren

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THE DISTRIBUTION OF MINERAL SALT IN NON-UNION OF FRACTURES

By

ULF NILSONNE

The mineralisation of a callus area during the healing process of experimentally obtained diaphyseal fractures in rats and dogs has been studied previously by the author by means of microradiographic techniques (7). It was then shown that the distribution of mineral salt at the different stages of healing reflected and magnified the inhomogeneous distribution of bone salt which exists in normal bone tissue. Quantitative microradiography gave a determination of the average bone salt concentration in the various callus structures. The periosteal callus showed the most rapid mineralisation, whereas the intermediately situated callus was mineralised at a slower rate. The complete process from the fresh fracture to full mineralisation of the callus area took, however, a very long time. Thus in the rat fracture the difference in the average mineralisation of the callus and of the ends of the fractures were not equalised until 1½ years later. The corresponding period for dog fractures was more than two years.

The results obtained from these studies of mineralisation in the healing of experimental fractures are not immediately applicable to fractures in man, nevertheless the skeleton of dogs at least closely corresponds with that of man in its microscopic structure and its reactions. It can therefore be expected that a microradiographic investigation of the conditions of mineralisation in clinical fractures will give results analogous to those in experimental fractures. On the other hand, for practical reasons it is difficult to carry out an investigation of this kind on clinical material. It would, for example, involve making consecutive biopsies on a callus area in order to obtain microradiographic specimens. This method would, however, mean a disruption of the biological process of healing, and consequently provide less significant information.

In contrast by studying established pseudarthroses in clinical cases with microradiographical techniques it is possible to observe the accumulation of bone salt in the callus It is true that this method allows the investigation of only a stationary stage in the development of the callus at a time when mineralised bone structures are no longer being formed across the fracture gap It will be shown in the following however that a study of the distribution of mineral salt in the tissue of pseudarthroses permits certain indirect conclusions to be drawn concerning the dynamic processes involved in the calcification of a fracture callus

The present investigation has been carried out on 10 clinical cases of non union of diaphyseal fractures of the long bones which have been admitted for orthopaedic treatment From a strictly biological point of view this non union should have manifested itself in the form of a real pseudarthrosis which perhaps should be called ne arthrosis That is to say the ends of the fracture are surrounded by some kind of synovial membrane and the space between them is filled with synovial fluid With modern methods of treating fractures, however such a definite stage of non union is rarely met therapeutic action is now normally taken when it is apparent that delayed union is about to become non union

In the present investigation the term pseudarthrosis has therefore been given its clinical meaning The material consists of fractures which in spite of the usual methods of reduction and fixation have not attained stability within a normal healing period but have displayed mobility and given rise to pain in the callus area Macroscopic X ray pictures have shown typical changes including sclerosed rounded fracture ends on either side of the pseudarthrosis gap The pseudarthrosis areas have been resected in toto during reconstructive surgery and a few centimetres of the fracture ends have been removed This method has made it possible to study the microscopic distribution of mineral salt at varying distances from the topographical centre of the pseudarthrosis The preparative and microradiographic methods used were identical with techniques described previously (7)

RESULTS

Fig 1 shows the microradiographic cross section of an ulna some millimetres from the pseudarthrosis gap in an 8 months old fracture The bone itself contains a comparatively large number of resorption

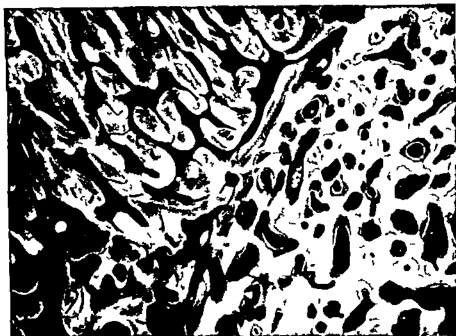


Fig 1

Microradiogram of a cross section some mm from the fracture line in non union of ulna 8 months after fracture Ulna right periosteal callus left Magnification 23 ×

zones but otherwise exhibits a normal structure and retained Haversian systems The distribution of mineral salt in the bone does not depart from that found in undamaged bone Thus it is possible to see typical Haversian systems showing varying degrees of mineralisation as well as a similar inhomogeneous distribution of bone salt in the intermediate zones Judged microradiographically the ends of the fractures do not therefore display any sign of homogenetation either in the form of hyper or hypo mineralisation The periosteal callus consists of coarse trabeculae closely packed together they display varying degrees of mineralisation usually with an increased accumulation of bone salt at the centre The distribution of mineral salt is in fact identical with the distribution found in the periosteal callus during the later stages of healing of diaphyseal fractures in dogs (Fig 2)

Fig 3 is the microradiogram of a longitudinal section through the pseudarthrosis gap in the same case as in Fig 1 The same mineralisation pattern can be observed in both specimens in the periosteal callus as well as in the outermost parts of the fracture

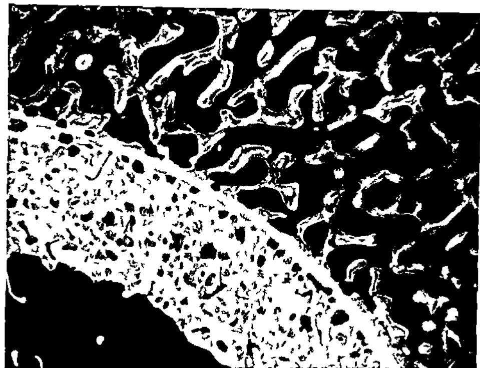


Fig. 2

Microradiogram of a cross section of a 4 months old femur fracture in the dog. Bone left, *periosteal callus right*. Magnification 21 ×

ends. In the intermediately situated callus a degree of mineralisation is displayed which is on average lower than in the periosteal callus. There are, however, wide local variations so that even adjacent structures may reveal considerable differences in mineralisation. This type of mineral salt distribution in the intermediate callus can be observed as far out towards the pseudarthrosis gap as the mineralised structures are in fact visible. A comparison with the femur fracture during healing in a dog shows remarkable similarities in mineral salt distribution (Fig. 4) notwithstanding the fact that this picture represents a progressive stage in healing, while Fig. 3 is of a stationary stage.

All the pseudarthroses investigated showed the same mineralisation pattern as the typical cases described above. From the results gained in connection with the reaction of the mineral phase in experimentally obtained callus tissue (7), it can thus be stated that analogous conditions exist between the distribution of mineral salt in normal

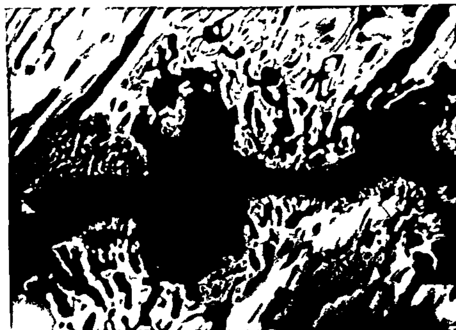


Fig 3

Microradiogram of a longitudinal section through the pseudarthrosis group in the same case as in Fig 1. The black area in the centre represents the unmineralised part of the pseudarthrosis. Magnification 10 ×

callus tissue and its distribution in pseudarthrosis tissue. The mineralisation which was observed in the pseudarthroses corresponds in the experimental callus material to a comparatively late stage of healing. The quantitative microradiographs which has been carried out also supports the observation that the average bone salt concentration in the mineralised structures of pseudarthrosis tissue corresponds to a stage which displays a relatively high degree of mineralisation.

DISCUSSION

In clinical studies of the causes of pseudarthrosis great interest has usually been paid to the primary methods of fracture treatment. This is natural enough since, to mention one reason alone, the anatomical results of the method applied can be studied directly in the clinical X-ray picture. During the healing process it is also customary to let the macroscopic X-ray picture be decisive in the assessment of the callus development and its function. As previously shown (4, 7)

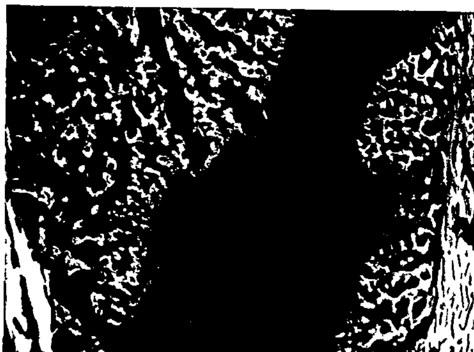


Fig 4

Microradiogram of a longitudinal section through the fracture region in a 4 months old femur fracture in the dog The black area in the centre represents the not yet mineralised part of the callus Magnification 17 ×

however macroscopic X ray pictures give incomplete information about the mineral salt contents of callus tissue The present microradiographic investigation has on the other hand made it possible to analyse in detail the distribution of mineral salt in pseudarthrosis tissue

A macroscopic X ray picture is also liable to lead to an assessment of fracture healing which is *based solely on the degree of calcification* in this way non union is interpreted as a defect in the mineralisation capacity as such Consequently a vast number of experimental and clinical investigations have been carried out with the aim of discovering some abnormality in the calcium or phosphorus metabolism of healing fractures No disturbance of these factors has however been revealed either in normal experimental animals or in normal persons on normal diet (for a survey see (2)) And *Urist* (8) states that The humoral source of bone salt is essential for the normal progress of healing

Thus if the humoral factors can be assumed to be normal it remains to see how they act in the callus tissue In the building of this tissue

interaction takes place between the organic and the inorganic phases which consist of organic matrix and the bone salt respectively. Ossification and calcification in normal embryonic and post fetal bone formation have been shown (1 a) to occur practically simultaneously. This means therefore that the organic matrix is ready to be mineralised at the same moment as it is formed and the same condition would also seem to exist in the building of callus tissue. Thus *Urist & McLean* (9) have found through histological investigations of tibia fractures in rats that the organic matrix in the periosteal callus is calcified as soon as it is formed. The same authors also write (6) that "The process of calcification of bone matrix in a healing fracture also closely resembles that of calcification of growing bone. Experimental data therefore indicates that osteogenesis and mineralisation appear simultaneously in normal bone growth and fracture healing.

Thus a necessary condition for the occurrence of pseudarthrosis is evidently a disturbance either of the organic or of the inorganic phase or of both simultaneously. In the present investigation it has been shown that the distribution of mineral salt in a pseudarthrosis area is analogous to the distribution found in healing stages of experimental fractures before mineralised structures have bridged the fracture gap. The mineralisation patterns have been found to be practically identical both in the fracture ends and in the periosteal and the intermediately situated callus. As far as the pseudarthrosis area is concerned this means that normal interaction has taken place between the organic matrix and the bone salt at those places where mineralised structures have been formed that is up to the pseudarthrosis gap. In the healing fractures which have been used here as comparative material (7) it must be assumed that the organic matrix is normally calcifiable since a normal healing sequence has occurred. Thus the non mineralised area in the fracture gap which can be seen in Fig. 4 contains normally calcifiable organic matrix.

In microradiograms of cases of non union it is possible also to see a central non mineralised area corresponding to the pseudarthrosis gap (Fig. 3). The organic matrix in this area has *evidently not been mineralised*. Had osteogenesis taken place normally as it should according to the preceding discussion the process of calcification could have continued across this area as well. The analogous distribution of mineral salt in the callus in cases of non union and of healing fractures indicates that the local mineralisation process has not been disturbed. This normal wave of mineralisation should in other words be capable

of spreading out between the fracture ends provided that it meets an organic matrix which is normally calcifiable. It is evident that no such development takes place in cases of pseudarthrosis. The probable conclusion can therefore be drawn that non union is not connected with a primary disturbance of the mineralisation process but with a change in the organic matrix which diminishes or prevents its calcifiability. Similar opinions as to the cause of pseudarthrosis have been expressed by *Karcher* (4) who found approximately the same uptake of isotopes in experimental fractures and pseudarthroses when using Ca^{45} and P^{32}. From these results he concluded that the local mineral salt contents was not affected in either case.

Further investigations using biophysical methods aim at studying the ultra structure and change of mass of the organic phase during fracture healing and its relation to the mineral phase.

SUMMARY

Microradiographic investigations have been carried out on clinical cases of non union of fractures. The distribution of mineral salt in the pseudarthrosis area is described in detail. A comparison between experimental fractures and pseudarthroses reveals in both cases an analogous distribution of mineral salt in the callus areas. This fact makes it probable that non union is not the result of a primary disturbance of the mineralisation process but rather of a change in the organic matrix which diminishes or prevents its calcifiability.

RÉSUMÉ

Des investigations microradiographiques ont été pratiquées dans des cas cliniques de non soudure de fractures. La distribution du sel minéral dans la pseudarthrose est décrite en détail. Une comparaison entre des fractures expérimentales et la pseudarthrose révèle dans les deux cas une distribution analogue du sel minéral dans le cal. Ce fait rend probable que la non consolidation n'est pas le résultat d'un trouble primaire du processus de minéralisation mais plutôt une altération de la matière organique qui diminue ou abolit son pouvoir de calcification.

ZUSAMMENFASSUNG

Mikroröntgenologische Untersuchungen wurden an klinischen Fällen von ungeheilten Brüchen ausgeführt. Die Verteilung von Mine-

ralsalzen im Pseudarthrosengebiete wird im Einzelnen beschrieben. Ein Vergleich zwischen experimentellen Brüchen und Pseudarthrosen zeigt in beiden Fällen eine gleichartige Verteilung von Mineralsalzen im Kallusgebiete. Diese Tatsache macht es wahrscheinlich, dass Nichtheilung nicht das Ergebnis einer Störung des primären Mineralisationsprozesses ist, sondern eher einer Veränderung der organischen Grundsubstanz, welche deren Fähigkeit zur Kalkaufname herabsetzt oder verhindert.

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UPTAKE OF Sr^{85} IN NON-MALIGNANT VERTEBRAL LESIONS IN MAN

By

GÖRAN C. H. BAUER and PAOLO SCOCCIANTI

INTRODUCTION

Shortly after intravenous injection of bone seeking tracers like alizarine sulphonate, lead, certain tetracyclines, radioactive calcium, strontium or barium, high concentrations of tracer will be found in areas where bone formations is active. With the aid of such tracers it is possible to locate areas of active bone metabolism occurring normally during growth and remodeling (for example calcifying metaphyseal cartilage, haversian systems) or pathologically (for example fracture, tumor, infection of bone). The ease of detection make radioactive tracers generally more useful than non-radioactive tracers. This is especially true of γ-emitting radioactive isotopes which may be detected *in vivo* with externally located scintillation detectors. Under clinical conditions this is an advantage over β-emitting isotopes which can usually be detected only in bone obtained at biopsy.

Bauer & Wendeberg (1959) have shown that in man external γ-counting of Ca^{47} and Sr may be useful for detection and delineation of localized bone lesions like fracture and tumor and for measurements of the rate of bone formation in such lesions. *Gynning et al.* (1961) have recently shown that this method can be used for detection of metastatic cancer in the spine.

This paper describes results of external counting over the spine following administration of Sr^{85} to human subjects with non-malignant vertebral lesions.

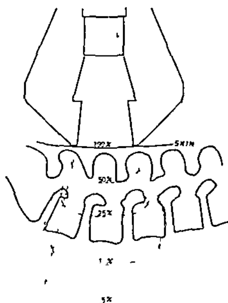


Fig. 1.
Equidensity curves (in water) of collimated crystal superimposed on linedrawing of lumbar spine. It is seen how the counter is more sensitive to Sr^{85} located in spinous processes than to Sr^{85} located in vertebral bodies.

MATERIAL

This study comprises 25 patients, 10 males and 15 females, ranging in age from 10 to 73 years (see Table 1).

The patients selected for study either had a localized lesion of the spine or were subjected to tracer studies of their bone metabolism kinetics because of more or less generalized disease. Individual diagnoses are recorded in Table 1.

METHODS

Isotope administration and detection

In general, the methods for Sr administration and detection used in this study were those described by *Bauer & Wendeberg* (1959). The carrier free Sr^{85} was injected intravenously at a dose not exceeding 1 μC per kg body weight, usually 50 μC total dose. This dose does not exceed the permissible weekly dose of 0.3 rad as recommended by the International Commission of Radiological Protection. The counting

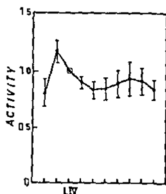


Fig. 2.

Normal pattern of externally recorded counting rate 14 days after intravenous injection of Sr85. This curve was obtained by pooling individual values of 7 patients without localized vertebral lesions (cases 1–7 of Table 1).—In each of these subjects each individual activity value recorded over the spinal counting levels on Day 14 was expressed as fraction of that recorded over L-IV. These values were pooled to give a mean value with standard deviation for each level counted over the spine. These mean values were plotted on the ordinate of a linear diagram in which the levels counted formed the abscissa. For comparison with data in individual cases this curve has been drawn as a broken line in Figs. 3–13 and 15–[illegible].

equipment consisted of a collimated scintillation detector (Fig. 1), a linear amplifier, a single channel pulse analyser and a scaler. External counting was performed over several levels of the spine at 7 and 14 days (Days 7 and 14) following isotope injection. In a few cases measurements over the spinous process of the fourth lumbar vertebra (L-IV) only were carried out daily.

In each patient L-IV was used as a landmark for positioning the detector. Starting from this point the activity was recorded at equidistant levels 5 cm. apart in line with the spineous processes (see Fig. 2). Usually two levels distal to L-IV and seven proximal to L-IV were counted. No measurements were carried out over the cervical spine. The head of the collimator was kept parallel to the desk on which the patient was lying in the prone position. Owing to the curved configuration of the spine the collimator usually touched the patient's skin only with part of its border. At each measurement 1 000 impulses were recorded. No measurements were accepted in which the probable standard error of the net counting rate was higher than 5 per cent.

In addition to each measurement over the spine, the activities over knees and thighs were recorded as previously described (2).

Correction for physical decay of the isotope was made by expressing

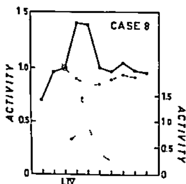


Fig 3

Case 8 a 68 year old man with crush fracture of L-I The injury occurred one month prior to isotope study Dotted curve shows activity recordings (in arbitrary values) with narrow (24 mm) cylindrical collimator Broken curve represents normal value (see Fig 2)

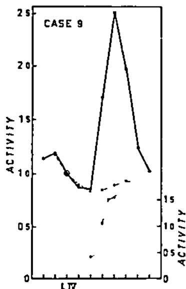


Fig 4

Case 9 a 34 year old woman with crush fractures of Th VIII IX and X The injury occurred one month prior to isotope study Dotted curve shows activity recordings (in arbitrary values) with narrow (24 mm) cylindrical collimator Broken curve represents normal values (see Fig 2)

all externally recorded activities as percentage of the counting rate of a standard sample of Sr 85 measured immediately before or after recordings in patients

A few patients received a second injection after an interval of some months (see Table I)

Representation of results

The material was divided into two groups according to presence or absence of vertebral lesions The former group comprised seven subjects in whom radiographic examinations failed to reveal any spinal disease In each of these subjects each individual activity value recorded over the spinal counting levels on Day 14 was expressed as fraction of that recorded over L IV These values were pooled to give a mean value with standard deviation for each level counted over the spine These mean

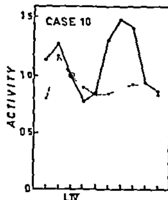


Fig 5

Case 10 a 73 year old woman with crush fracture of Th-IX The injury occurred 2 months prior to isotope study Broken curve represents normal values (see Fig 2)

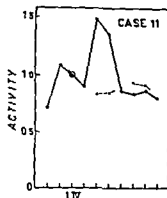


Fig 6

Case 11 a 23 year-old man with crush fracture of L-I The injury occurred 2 months prior to isotope study Broken curve represents normal values (see Fig 2)

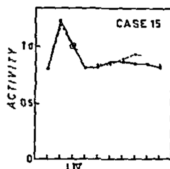


Fig 7

Case 15 a 55 year-old woman with crush fracture of Th-XII The injury occurred 8 months prior to isotope study Broken curve represents normal values (see Fig 2) The uptake pattern is considered normal

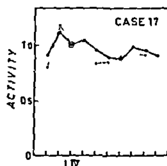


Fig 8

Case 17 a 57 year old woman with crush fracture of L-II The injury occurred 2 years prior to isotope study Broken curve represents normal values (see Fig 2) The uptake pattern is considered normal

values were plotted on the ordinate of a linear diagram in which the levels counted formed the abscissa The curve shown in this diagram (Fig 2) forms the basis for evaluation of the individual spinal activity patterns recorded in cases with vertebral lesions When the pathological lesion was situated close to L-IV the spinal activity values were normalized with respect to one of the counting levels over the thoracic spine rather than L-IV (see Figs 9 and 11)

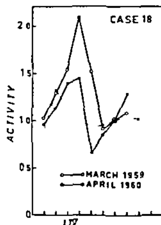


Fig 9

Case 18 a 59 year-old w man with a tuberculous spondylitis f L II known since 1 year prior to fir t isotope study The second is tope study was made when general an l local condi tion had improved after immobiliza ti n in plaster and antibi tic therapy Br ken curve repre ents normal values (see Fig 2) All values have been n r malized t a c unting level over th racic spine rather than to L IV

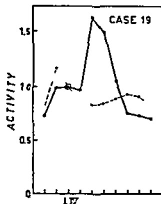


Fig 10

Ca e 19 a 39 year-old w man with a tul ercul us sp ndylitis f Th-XII and L-I known since 1 year pri r t iso-t pe tudy Br ken curve repre ents n rmal values (ee Fig 2)

A deviation from the normal pattern in any level counted by more than twice the standard deviation of the normal mean value was used as a criterion for abnormal activity pattern

When countings were made at several time intervals following isotope administration time was abscissa instead of the levels counted

In each case the activity ratio spine (L-IV) knee was determined on Days 7 and 14 In addition similar ratios were determined for spine (lesion) knee in cases with vertebral lesions (Table 1)

RESULTS

The results are expressed as detailed above and are recorded in Table 1 and Figs 1-13

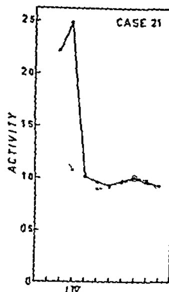


Fig 11
Case 21 a 47 year old woman with non specific discitis following removal of a disc herniation in the L-V—S I interspace The isotope study was made 8 months after operation Broken curve represents normal values (see Fig 2) All values have been normalized to a counting level over thoracic spine rather than to L IV

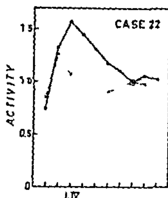


Fig 12
Case 22 a 61 year old woman with spondylarthritic changes especially marked in lumbar spine Broken curve represents normal values (see Fig 2) All values have been normalized to a counting level over thoracic spine rather than to L-IV

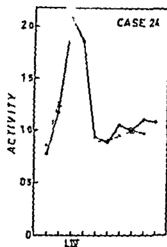


Fig 13
Case 24 a 50 year old woman with spondylolysis of L-III Broken curve represents normal value (see Fig 2) All values have been normalized to a counting level over thoracic spine rather than to L IV

Cases without vertebral lesions (cases 1-7 Fig 2)

Data were pooled from measurements on Day 14 in seven individuals without X ray or other signs of localized vertebral lesions (Fig 2) Two regions with higher uptake are seen one over the sternum and another less marked over the thoracic spine

Cases with localized vertebral lesions

(a) *Vertebral fracture* (cases 8–17 Figs 3–8)

In most of the cases studied a marked activity peak was found over the fractured vertebra(s) and usually also over adjacent vertebras In one case a wide peak was apparently *due to the fact that the fracture* was located between two adjacent levels counted (Fig 3) In two cases only the activity pattern did not significantly deviate from the basic pattern (Figs 7 and 8)

(b) *Spondylitis* (cases 18–21 Figs 9–11)

A higher uptake was seen over the lesion in two of the three cases with a *tuberculous spondylitis* (Figs 9 and 10) while in the third patient the uptake pattern did not deviate from normal (case 20) One *patient (Fig 9) was injected twice The second administration* was given after about 1 year of immobilization in plaster and antibiotic therapy The second activity pattern was similar to the first with the noteable exception that the counting rate over the lesion site was markedly reduced

In a case of *non specific discitis* after removal of a disc herniation an activity peak was seen over the lesion (Fig 11)

(c) *Other localized vertebral lesions* (cases 22–25 Figs 12 and 13)

Two cases of marked *spondylarthrosis deformans* were studied one with an abnormal uptake pattern (Fig 12) and another (case 23) with an uptake pattern which did not deviate from normal

One case of lumbar *spondylolysis* had a peak uptake over the lesion (Fig 13)

A normal uptake pattern was found in a case with a *lytic lesion* of unknown origin in the tenth thoracic spinous process (case 25)

DISCUSSION

Evaluation of external counting over localized vertebral lesions is complicated by (a) activity in adjacent tissues (b) activity in bowel or bladder and (c) lack of a suitable reference

(a) Activity in soft tissues and adjacent metabolically active bone tend to bury that of a pathological lesion It is known from earlier studies however that the soft tissue/bone activity ratio decreases during the initial 14 days following intravenous injection of Sr and this seems *to hold also for the normal bone/fractured bone activity* ratio (2 4) It was therefore decided to use the measurements made on Day 14 as a basis for comparison between subjects The validity of this

decision is emphasized by the finding that the activity ratios spine (L–IV)/knee and spine (lesion)/knee increased from Day 7 to Day 14 in most of the subjects studied (Table 1).

(b) Activity excreted into the bowel or bladder may interfere with measurements over the spine. For example, the effect of slow bowel movements on activity measurements over the spine is illustrated in Fig. 14. For this reason, also, Day 14 will provide more reliable data than would earlier intervals.

(c) Comparison of measurements over the right and left legs or arms may serve as a basis for evaluation of results of external counting over the extremities. It is difficult to provide such a basis for spinal activity measurements. However, the results of this study confirm those of *Gynning et al.* that variation between subjects without X-ray or other evidence of localized spinal lesion is sufficiently small to allow construction of a reasonably reliable basic activity pattern for comparison with individual pathologic cases. It should be emphasized that the shape of this basic pattern is influenced by the detection apparatus used (for example size and shape of crystal and collimator).

A deviation from the basic pattern strongly suggests a pathological process in the spine. In one case studied in this laboratory it was found, however, that a large kidney stone caused a marked rise in the counting rate recorded over the adjacent spinous process (Fig. 15).

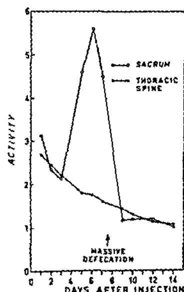


Fig. 14.
An isotope study was made in a 55-year-old man suffering from osteopenia. This graph shows the counting rate over the sacrum and the thoracic spine up to 14 days following intravenous injection of Sr^{85}. The peak counting rate over the sacrum was due to Sr^{85} in the bowel. The activity is expressed as fraction of counting rate over sacrum on Day 14. All values have been corrected for background and decay.

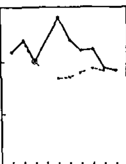


Fig 15 a



Fig 15 b

Fig 15

An isotope study was made in a 24 year old woman with stones in her left kidney. A high counting rate was observed over adjacent spinous processes (Fig 15 a). The counting rate over the left kidney was higher than over the right kidney (Fig 15 b). After surgical removal of the stones, their external layers were found to contain Sr^{85}.

SUMMARY

With the aid of an externally located scintillation counter it was possible to demonstrate an increased spinal uptake of intravenously injected Sr^{85} in cases of vertebral fracture, spondylitis and other types of localized vertebral lesions.

RÉSUMÉ

A l'aide d'un compteur par scintillation placé extérieurement, il a été possible de démontrer une absorption spinale accrue de Sr^{85} injecté intraveineusement dans les cas de fractures vertébrales, de spondylite et d'autres types de lésions vertébrales localisées.

TABLE 1

The pooled Day 14 uptake data of patients 1–7 were used to build up the general pattern (Fig. 2).—In most cases the spine (healthy region)/knee ratios were found to increase from Day 7 to Day 14. This tendency was more marked for the spine (lesion)/knee ratios.—A further analysis of these ratios is in progress

	Case	Sex	Age (years)	Diagnosis	Spine (normal) knee ratio			Spine (lesion) knee ratio		
					Day 7	Day 14	% change from Day 7 to Day 14	Day 7	Day 14	% change from Day 7 to Day 14
1	C 52	M	15	Back insufficience	44	50	+13 7			
2	C 172	F	27	Nephrolithiasis	1 41	1 89	+34 0			
3	C 147	M	37	Hypogonadism	84	86	+ 2 4			
4	D 4	M	33	Nephrolithiasis	1 78	2 12	+19 1			
5	B 102	F	17	Nephrolithiasis	1 27	1 48	+16 5			
6	C 4	F	53	Nephrolithiasis (clin. normal after parathyroidectomy)	84	82	— 2 4			
7	D 56	M	40	Nephrolithiasis after nephrectomy	1 24	1 23	— 8			
8	D 26	M	68	L 1 fracture (1 month after inj.)	1 55	1 76	+13 5	1 87	2 50	+33 7
9	D 57	F	34	Th VIII IX and X fractures (1 month after inj.)	1 22	1 45	+18 8	2 87	3 69	+28 6
10	C 153	F	73	Th IX fracture (2 months after inj.)	1 31	1 48	+13 0	1 41	1 75	+24 1
11	C 114	M	22	L 1 fracture (2 months after inj.)	1 16	1 06	— 8 6	1 33	1 91	— 1 04
12	D 5	M	65	L IV fracture (2 months after inj.)	1 17	1 27	+ 8 5	1 96	2 70	+37 7
13	C 134	F	33	Th VIII fracture (4 months after inj.)	1 24	1 26	+ 1 6	1 30	1 61	+22 0
14	D 43	F	55	Th XII [illegible]						

				fracture (6 months after inj.)	1.38	1.31	−5.6	2.74 4.65	3.13 5.45	+14.[illegible] (over L IV) +17.[illegible] (over Th XII)
15	C 22	F	59	Th XII fracture (8 months after inj.)	1.80	2.22	+23.4	1.50	1.31	+27.3
16	D 3	M	40	Sacrum I and Th XII fractures (10 months after inj.)	1.48	1.70	+14.8	1.59 1.59	2.56 2.11	+58.5 (over sacrum) +32.7 (over Th XII and L-I)
17	C 111	F	57	L II fracture (2 years after inj.)	1.09	1.16	+7.4	1.29	1.38	+8.5
18	C 48	F	53	L III tbc spondylitis (1st injection)	1.41	1.55	+9.9	.51	[illegible]	+31.1
				(2nd injection 13 months later)	1.0	.98	−6.6	1.25	1.41	+13.6
19	C 129	F	33	L I and Th XII tbc spondylitis	1.51	1.38	−8.6	2.01	.09	0.0
20	C 16	M	10	L III tbc spondylitis	.52	.56	+7.7	.72	.74	+2.8
21	D 66	F	47	L V-S I non specific spondylitis after removal of herniated disc	1.72	2.06	+19.8	4.49	5.39	+20.0
22	D 3	F	51	Spondylarthrosis deformans with marked change in lumbar spine	1.02	1.15	+12.[illegible]	1.41	1.81	+28.4
23	D 27	M	55	Spondylarthrosis deformans with marked change in lumbar spine	1.37	1.83	+31.7	1.40	1.92	+37.0
24	C 152	F	50	L III spondylolysis	1.30	1.59	+21.5	2.0	2.94	+4[illegible].8
25	C 151	F	50	[illegible] of unknown origin in the Th X spinous process	1.35	1.57	+16.3	1.30	1.37	+5.4

ZUSAMMENFASSUNG

Mit Hilfe eines ausserhalb aufgesetzten Funkenzählers war es möglich, eine erhöhte spinale Aufnahme von intravenös injiziertem Sr^{85} in Fällen von Wirbelbrüchen, Spondylitis und anderen Typen von örtlichen Wirbelsäulenschäden nachzuweisen.

ACKNOWLEDGEMENTS

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FROM THE ORTHOPAEDIC DEPARTMENT, UNIVERSITY OF GOTHENBURG, SWEDEN. HEAD: PROFESSOR CARL HIRSCH, M.D.

STRAINS AND STRESSES IN THE UPPER FEMUR STUDIED BY THE STRESSCOAT METHOD

By

RAGNAR KALEN

Strain and stress analysis in bone may be made by three methods: 1) studies of sections or excised specimens of bone, 2) studies of models of bone, or 3) studies of whole bone (Evans 1957).

1) Mathematical analysis of sections and strain and stress analysis on excised specimens of bone was the first of these methods to be used. Von Meyer (1867) and Wolf (1870) among others studied the orientation of the trabeculae in sections of bone. Koch (1920), Grunewald (1920) and other authors made mathematical analyses on transverse sections of bone under assumed conditions of stress. Rauber (1876), Hulsen (1896) and Evans (1951) have made stress and strain analyses using standardized sections of bone. Forsblad (1959) has determined the elastic properties in sections of bone taken from various sites on the human femur.

Due to the complicated architecture of bone and the heterogeneous nature of this biologic material, however, this type of study does not provide an accurate idea of the strain distribution in whole bone.

2) For stress and strain analysis in bone by means of model studies several techniques have been adopted. Roux (1870) used paraffin-coated rubber models. Under a certain strain the paraffin cracked, the direction of the cracks indicating the distribution of the stresses. A later method, used for instance by Hallerman (1934) and Pauwels (1948), is the photoelastic technique commonly used in industry. With this method a plastic model is loaded and by transillumination with polarized light the distribution of the strains can be registered photographically.

The disadvantage of these techniques based on model studies is

however that they presuppose a solid construction and a homogeneous material requirements which are not met by bone

3) In order to reach an understanding of strain conditions in the whole bone therefore the only feasible method appears to be to employ whole bone as the test object In such studies what may be measured is in addition to the applied stress the strain i e the change in length occurring in the outer surface of the test object under a certain stress Calculations may be based on Hook s law which says that the strain is proportional to the causative stress

A highly accurate method of measuring strain is afforded by the strain gauge technique With this technique the change in length is registered electrically by measuring the alteration in the electrical resistance of a metal wire resulting from a change in its length A condition for obtaining reliable results with this method is that the strain gauges be applied in the direction of the stresses The orientation of the stresses cannot be determined from the strain gauges

By using some kind of strain sensitive lacquer it is possible to determine the surface strain distribution and the direction of the stresses Kuntscher (1934) used colophonium applied in melted form A considerably simpler version of this method which has become known under the trade name Stresscoat was developed by Forester and Ellis (1940) Gurdjian and Lissner (1945) were the first to use it in studies of bone Subsequently Evans et al and Frankel have reported on several studies in which this technique was used

The procedure is as follows The test object is first sprayed with aluminum dye providing a dull silvery undercoating and subsequently with a special lacquer After this has dried for 24 hours the specimen is ready for testing When the specimen is loaded the lacquer cracks Both tensile and compressive strains produce this result although in the latter case only when the load is released The cracks lie at right angles to the direction of the stresses The number of cracks per unit of length is proportional to the applied stress The location of the initial cracks indicates where failure will occur if the load is increased to breaking point By spraying a calibration rod simultaneously with the specimen and loading it under standardized conditions it is possible to determine the actual sensitivity of the lacquer that is the specific amount of strain required to produce cracks (Fig 1) This sensitivity is influenced by temperature and humidity conditions lacquers of different sensitivity are available to permit adaptation to varying conditions The cracks are visible under obliquely directed light (Fig 2)

Fig. 8

Calibration rod mounted in the testing device which produces a constant stress on the rod. The higher the lacquer sensitivity the further the cracks extend down the surface of the rod. Next to it a calibration rod in the measuring stick which shows a specific strain of .0006 in/inch representing the actual sensitivity of the lacquer.

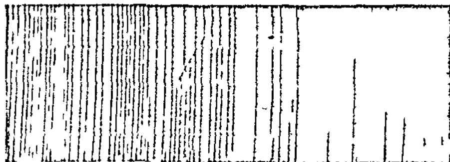


Fig. 9

Calibration rod with cracks visualized under obliquely directed light.

In order to emphasize them a special red dye is available which is brushed over the tested surface where it penetrates into the cracks A disadvantage of this dye treatment is that the lacquer loses its strain sensitive properties which makes it impossible to increase the load and record the resulting new cracks Another method to make the cracks more visible is provided by using an electrostatic powder Statiflux which collects along the cracks With this method the sensitivity of the lacquer remains intact A third and extremely simple method is to mark the cracks as they appear with a fine paintbrush dipped in india ink

If the specific strain under which the lacquer cracks is known the method may also be used for qualitative measurements It is more complicated to use however and less reliable than the strain gauge method but as a qualitative complement to the latter it is extremely useful

In studies of bone by these methods the bone is regarded as a hollow structure and the distribution of the strains is measured at the surface The actual stresses acting in the trabecular system inside the bone cannot be measured directly but as they will be projected onto the surface at the sites of attachment of the trabeculae to the wall of the structure one may also indirectly record the changes in the strain pattern inside the bone

In static loading in which the femur was oriented vertically and the femoral head placed in line with the center of the supporting surface with the load applied to the head in the same line the first cracks appeared on the superior aspect of the neck slightly lateral to the center (Fig 3) This concentration of cracks indicated the site of highest tensile strain With increasing load further cracks appeared on the lateral aspect of the shaft The highest compressive strain was found on the inferior cortex of the neck Additional cracks arose on the superior medial aspect of the femoral shaft when the load was further increased On the aspect of the bone subjected to compressive strain the load required to produce cracks was higher than in the area of tensile strain The cracks were oriented perpendicular to the long axis of the loaded area These results confirmed Evans's concept of the femur behaving like an eccentrically loaded column subjected to a bending action Tensile strain was produced on the convex aspect of the bone compressive strain on the concave aspect (Fig 4)

In another series of tests static loads were applied to the head with the long axis of the neck kept in horizontal position and the supporting



Fig 3
Proximal end of the femur mounted vertically and loaded in an Amsler compression machine The highest strain appears on the superior lateral aspect of the shaft and on the superior aspect of the neck

surface at the distal end of the neck (Fig 5) The loads were applied in five different positions A E (Fig 6) achieved by rotation around the long axis of the neck In position A the inferior cortex of the neck was directed upwards and was the site of highest tensile strain in B it was the anterior cortex in C the anterior superior cortex in D the posterior superior cortex and in E the posterior cortex The area subjected to the most extensive tensile strain was in each instance treated with Stresscoat In all tests lacquer with a sensitivity of 0 0009 inches inch was used The tests invariably showed that the minimum load necessary to create a tensile strain in the loaded surface sufficient to produce cracks was highest in position A (Fig 7)

The main direction of the cracks was always perpendicular to the long axis The first cracks appeared on the distal half of the neck that is at the site of highest strain The dimensions of the neck with a smaller diameter in the sagittal plane as compared to the frontal plane and consequently a higher degree of rigidity in the latter as well as the larger dimensions of the inferior cortex explain the higher loading



Fig 4

Proximal end of the femur under vertical loading. Tensile strain is produced on the superior cortex of the neck and the superior lateral aspect of the shaft. Compressive strain appears laterally on the inferior cortex of the neck and on the superior medial aspect of the shaft. The cracks on the aspect of the bone under tensile strain extend further down the shaft than in the area of compressive strain.

values obtained in position A. The tests were made on fresh autopsy bone stored in a deep freezer.

Position	Average load under which the first cracks appeared
A	62.5 kg
B	34
C	35 –
D	46 –
E	29 –

In order to estimate the influence of this method of storage on the results the same tests were repeated on two femurs stored at room temperature for 6 months. Similar strain patterns were obtained in these tests but it proved necessary to increase the load required to produce cracks by 30 per cent on an average, showing that the elasticity of the bone had decreased.

SUMMARY

The Stresscoat technique may be profitably employed in studies of bone. The method is elaborate and required training. For quantitative determinations the method is not as reliable as the strain gauge



Fig 5

Proximal end of the femur with the load applied to the inferior cortex of the head and with the neck in a horizontal position

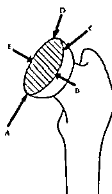


Fig 6

Diagram of the load directions used in the test described in the text in which the head was loaded with the long axis of the neck orientated horizontally

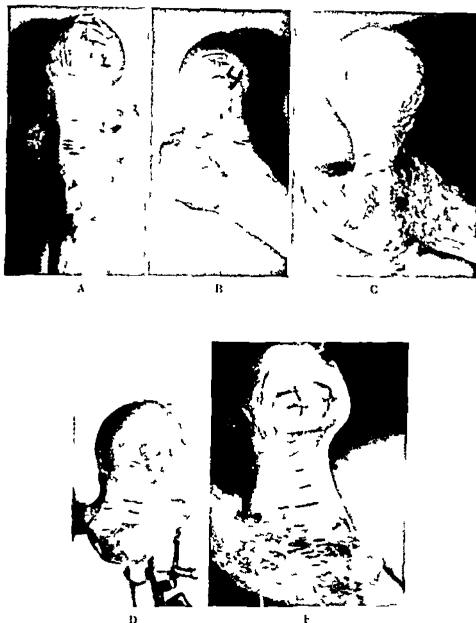


Fig 7

The pictures show the patterns of strain produced by loading the femur in positions A–E as described in the text Note that the first cracks appear on the lateral aspect of the neck at right angles to the long axis of the neck

technique In stress and strain analysis of a structure as complex as bone it is on the other hand a necessary complement to the strain gauge technique as it indicates the direction of the stresses on the surface of the bone and the site of maximum strain

Preliminary studies were made on the femur Forces from different directions were applied to the femoral head and the distribution of the stress in the femoral neck was recorded The concentration of the cracks in the lacquer indicated the site of greatest strain The number of cracks increased with increasing force The cracks were orientated largely perpendicular to the longitudinal axis of the femoral neck The site and number of cracks varied with the magnitude and direction of the force The smallest force necessary to produce cracks was largest when the greater trochanter was supported in external rotation while the inferior part of the head was loaded

RESUME

La technique de la couverture de tension peut etre profitablement utilisee pour l etude des os La méthode doit etre appliquee avec soin et demande de l entrainement Pour les déterminations quantitatives cette methode n est pas aussi sure que la technique de la jauge de l effort Dans l analyse de la tension et de l effort d une structure aussi complexe que celle de l os il faut d un autre cote un complement a la technique de la jauge de l effort indiquant la direction des tensions sur la surface de l os et le siege de l effort maximum

Des études preliminaires ont ete faites sur le femur Des forces venant de directions differentes ont ete appliquees a la tete femorale et la distribution de la tension sur le col femoral a ete enregistree La concentration des craquements de la laque indique le siege du plus grand effort Le nombre des craquements augmente avec l accroissement de la force Les craquements ont ete orientes d une maniere largement perpendiculaire a l axe longitudinal du col femoral Le siege et le nombre des craquements varient avec l importance et la direction de la force La plus petite force nécessaire pour produire un craquement a ete observee lorsque le grand trochanter etait supporte en rotation externe alors que la partie inferieure de la tete etait en charge

ZUSAMMENFASSUNG

Die "Stresscoat" Technik kann mit Vorteil zur Untersuchung von Knochen angewendet werden Die Methode ist kompliziert und erfordert



A B C



D E

Fig 7

The pictures show the patterns of strain produced by loading the femur in positions A–E as described in the text. Note that the first cracks appear on the lateral aspect of the neck at right angles to the long axis of the neck

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VASCULAR PROBLEMS IN ORTHOPAEDIC SURGERY

By

B. EJRUP and T. HIERTONN

In the same way that the surgery of protruded intervertebral discs has radically changed the treatment and research pertaining to sciatica, so has modern vascular surgery given new aspects to injuries and diseases of the peripheral arteries from both a clinical and research point of view. The ageing and degeneration of the arterial walls can not yet be influenced therapeutically, but complications such as thrombosis, aneurysms and arteriovenous fistulae are often suitable for surgical reparation. The previous pessimistic outlook on arteriosclerosis has been replaced by a more optimistic and active attitude.

During the 10 year period that we at Norrbackainstitutet have been engaged in peripheral vascular surgery a fascinating development in this field of endeavour has taken place throughout the whole world.

Our laboratory for peripheral vascular diseases gives us a firm basis for the team work which was shown to be necessary.

Even if the typical arteriosclerotic cases dominate, there are a good many other "orthopaedic cases" in which assessment of the state of the circulation is essential for exact diagnosis and therapy. *It is not unusual for chronic occlusive disease at the aortic bifurcation or in the iliac arteries to form basis of pain in the back and hip region,* and the symptoms are misinterpreted as lumbago or osteoarthritis. Some vascular cases are also *hidden among so-called foot insufficiencies.* A detailed history of the pain and simple palpation of the pulses should in the first place give valuable information about the arterial blockage and its location.

It can be more difficult to arrive at a correct conclusion with certain congenital vascular abnormalities with local or widespread hypertrophy of one extremity and a difference in leg length. *Chronic leg ulcers and chronic swelling of the legs are another field where the*

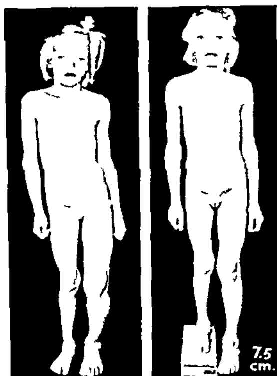


Fig. 1
8-year-old girl admitted because of hypertrophy of the left leg. Difference of 8 cm in leg length (Case 1).

arterial circulation—besides the venous and lymphatic—must be mapped out before operative treatment is undertaken. It is conceivable that in the future reconstruction may also be done on certain venous insufficiencies.

Of the many "vascular problems" which the orthopaedist meets, those which will be dealt with here are: congenital vascular abnormalities, traumatic arterial lesions, emboli and arteriosclerotic manifestations.

Congenital vascular anomalies and differences of leg length

The orthopaedist has several methods available when it comes to equalizing leg length discrepancies during growth or afterwards. Knowledge of the etiology is important. The congenital vascular abnormalities offer special problems, which is shown by the case related below.

OSCILLOMETRIC EXAMINATION

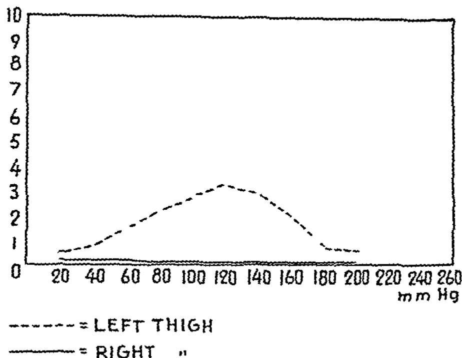


Fig 2

Oscillography normal readings on the left none on the right (Case 1)

Case 1 An 8 year-old girl who was *referred* to the orthopaedic clinic because of hypertrophy of the left leg (Fig 1) The leg length difference measured clinically was 8 cm and 8.5 cm according to measurement on survey roentgen film of the whole extremity The left thigh and calf were clearly thicker Skin temperature measurements showed no difference between the legs The right side had no pulses *in the groin at the knee nor on the foot Oscillometry showed no reading on the* right thigh and foreleg and normal readings on the left side (Fig. 2) Arteriography (Karolinska sjukhuset) showed no filling of the iliac and femoral artery on the right side (Fig 3) The investigation confirmed that this was not a question of hypertrophy and elongation of the left leg but rather an atrophy and delay of growth on the right side The difference in the leg length depended on an arterial insufficiency in the right lower extremity due to a congenital aplasia of the arteries In this case the femoral artery was lacking and therefore an arterioplasty could not be performed

In cases of congenital hypertrophy and atrophy with different leg lengths a complete analysis including angiography ought to be done with the thought that operable vascular stenoses and aplasias might be found



Fig. 3
Arteriography shows aplasia of the iliac and femoral arteries on the right side (Case 1)

Case 2. A girl of 15 years whose right leg was thicker, warmer and 4 cm. longer than the left. In the picture (Fig. 4) taken with infrared sensitive film an increase in the vein markings is clearly seen. Arteriovenous communications in the knee region were demonstrated by arteriography (Fig. 5). Ligation of the arteries and local injections of sclerosing solution diminished the swelling and the heavy feeling in the leg.

The symptoms of such vascular anomalies vary remarkably depending on their location locally or diffusely in the soft parts, joints

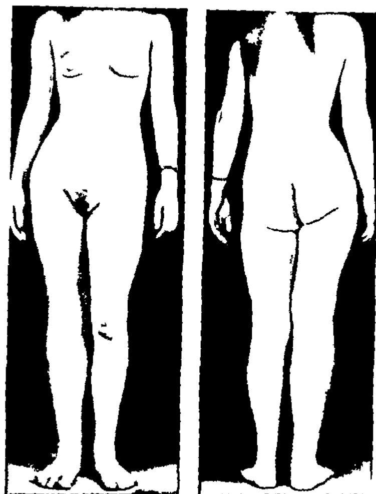


Fig 4

15 year old girl with the right leg thicker, warmer and 4 cm longer than the left. Observe the increased vein markings (Case [illegible])

or skeleton. In one case a circumscribed hemangioma in the suprapatellar bursa caused a peculiar overgrowth of the patella alone. In another case the appearance of the soft tissue changes was so diffuse and malignant that amputation was considered. In a third case hemangiomatous formations were localized to a limited part of the knee joint capsule and caused recurrent hemarthroses. The laborious diagnosis in these cases is worthwhile in order to preserve function through selective surgical interventions. The chances of interrupting a growth stimulation depend on the extent of the vascular changes and how early the diagnosis is obtained and treatment instituted.



Fig 5
Contrast injection via the inferior genicular artery with demonstration of the arteriovenous communication (Case 2)

Traumatic arterial lesions

The orthopaedist meets peripheral arterial contusions in for example supracondylar fractures and knee dislocations With serious signs of ischemia as with progressive paresis operative treatment must not be delayed too long Only fasciotomy and extensive liberation of the artery can save the function A contusion of the artery is often accompanied by a thrombosis If one can not obtain arterial flow through the damaged area it should be excised and the arterial continuity re established A direct end to end suture is best provided the tension is not too great in which case the defect should be bridged with a transplant

With multiple injuries and lacerations of the artery a reconstruction of the vascular stream can save even an apparently devitalized extremity as shown by the following example

Case 3 A 0 year old boy had his right arm crushed in a press machine Skin and muscle lacerations on the arm were dreadful the hand was dead white cold

and completely lacked sensibility and motor function. The fractured humerus lay exposed. In collaboration with the plastic surgeons at Karolinska sjukhuset an *exploration was begun with great doubts and reservation.* Continuity of the nerves was preserved and this was the deciding fact. The fracture was reduced and fixed by an intramedullary nail. An 8 cm long occluded segment of the brachial artery was excised. The flow was reconstituted with an autogenous vein graft. The transplant was covered with muscle and skin as well as possible. The patient was discharged from hospital with a good circulation and a mild ulnar paresis which gradually recovered.

In some cases we have used homologous transplants and thereby saved the acute situation. Experiences from Korea with acute cases showed, however, that in the long run vein transplants are better than homologous arterial transplants and vascular prostheses. This agrees with our own experiences. (*Hiertonn* 1960, *Ejrup & Hiertonn* 1960).

Peripheral arterial emboli

Regarding the peripheral emboli with grave ischemia and severe pain the indications for operation are clear. The earlier the operation the better the result. Neglected cases with manifest gangrene offer special problems. Despite lymphangitis and pain an arteriography ought to be done. This can namely lead to an arterial reconstruction and a secondary and more conservative amputation. Such a case will be briefly related.

Case 4. A farmer of sixty who previously had a below knee amputation on the left side was admitted to the orthopaedic clinic with obvious gangrene on the right foot after a new neglected embolus. (Fig. 6). Angiography showed an occlusion of the external iliac artery. (Fig. 7). A late embolectomy improved the circulation in the whole extremity so that the amputation could be performed at the line of demarcation. This became almost a transmetatarsal amputation which healed rather rapidly. *Circulation and walking ability both became excellent.*

Arteriosclerosis obliterans

With the present tendency toward an older population arteriosclerosis offers an increasing problem. Even now senile gangrene is a problem for the individual, the community and the doctor. The difficulty in rehabilitating the elderly above knee amputee needs no further elucidation here. These serious ischemias require full investigation by both the internists and surgeons. Before a more or less routine above knee amputation is performed it is valuable to take under consideration



Fig. 6.
Foot gangrene in a farmer of sixty years of age after a neglected embolus in the iliac artery. Previously amputated on the other side (Case 4).

1) if *infection* or *ischemia* is the dominating cause
2) if a vascular reconstruction or a sympathectomy possibly can improve the circulation
3) if the circulation is sufficient for a low amputation

We have often found that local surgical revisions in combination with general and local treatment of infection are worthwhile in arteriosclerotic gangrene. When the necrosis is excised and the infection brought under control the sparse circulation can be sufficient for secondary healing and amputation can be avoided. Oedema prophylaxis and treatment also have a very important place in the treatment of gangrene.

Arteriography is required to determine if a vascular reconstruction is possible, i.e. if a localized arterial occlusion is the principal factor. Even if the arteriosclerotic gangrene is a manifestation of widespread



Fig 7

Angiography showed an occlusion of the external iliac artery and a good lumen above This led to a successful vascular reconstruction (Case 4)

distal occlusions a reconstruction of a blockage in the femoral artery may produce a distal increased pressure with an improved flow through the collaterals

We have had good use of lumbar sympathectomy in those cases with diffuse changes in the arterial system especially where vascular reconstruction is not possible However it is difficult to give figures on the effect of sympathetic surgery Lumbar sympathectomy abolishes the vasoconstrictor tonus This is of special value in upright positions (*Fjrup* 1955) when we normally get an increased vasoconstrictor tonus

Even if above knee amputation is simpler and safer from a healing point of view than below knee amputation the rehabilitation is considerably more difficult Assessment of the state of the circulation by arteriography oscillography fluorescein testing and skin temperature measurement has resulted in several elderly patients having amputations below the knee with good results In this connection we would like to emphasize the importance of a strictly individualized amputation level

A study of over five hundred amputees who were rehabilitated at Norrbackainstitutet during the years 1951–1957 showed that vascular disease was the reason for the amputation in 55 % of the cases There is reason to hope that mechanical and medical prophylactic measures combined with increased surgical resources may reduce the frequency of severely disabled amputees

Regarding the operative treatment of claudication cases one can resect the occluded segment and sew in a transplant end to end This attends to the desire for excision of the diseased area and for improvement of the function It has been shown however that more cases can be operated on and with less risk if one avoids resection By pass without resection therefore is becoming most frequently employed For the anastomosis one can choose an area above and below the blockage with favourable condition of the walls and where one does not need to sacrifice important collaterals

Fig 8 is an example of a segmental occlusion in the femoral artery and surgical compensation of the blockage by an autogenous graft sewn in end to side

New materials for arterial replacement have stimulated interest and increased resources We have always preferred autogenous vein grafts when possible The operated cases have been followed with objective methods of study It is shown that a vein transplant is very reliable 75 % functioning after 3 6 years Beside the subjective symp-



Fig. 8.
Example of a by-pass operation. Occlusion in the adductor canal compensated by a free vein transplant from the long saphenous vein. Work test and walking ability became normal after operation.

toms and history, the testing of the walking capacity and the clinical examination with palpation of the pulses, oscillography has also been used as an objective measurement (*Ejrup & Hiertonn* 1960). The oscillography is performed both at rest and after controlled exercise. Fig. 9 shows before operation a long inverse recovery phase and muscle twitchings. After arterial reconstruction the curves are completely normal. Normally the inverse recovery period of the oscillogram is less than one minute. The oscillographic exercise test gives an indirect measure of the patient's capacity to increase his collateral blood flow over the resting flow and indirectly reflects the local circulatory capacity (stenosis + collaterals). For routine testing we have chosen an amount of exercise which corresponds to normal daily activity. Heavier work tests have also been used in a few cases. If the transplant becomes blocked this is reflected immediately in the exercise oscillogram by prolonged inverse reaction.

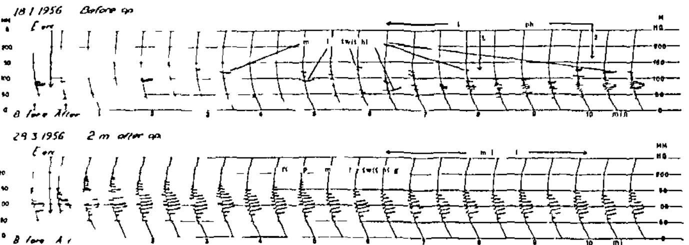


Fig. 3

[illegible] graphs after exercise before and after operation. Note normalization after arterial reconstruction

Homologous arterial grafts which opened the way to reconstructions on the central arteries have also been used peripherally but are now abandoned

Prostheses of dacron and teflon are employed more and more Thromboarterectomy is used with short occlusions in large calibre vessels If a localized thrombus lies near the mouth of a large arterial branch and the arterial wall is moreover, severely thickened one easily gets an unfavourable stenosis after thromboarterectomy To avoid this one can sew a "patch into the arteriotomy opening and the patch can be of autogenous vein or of a piece of dacron

With the above described methods of direct operative intervention in obliterative arterial diseases aneurysms and traumatic arterial lesions a whole new therapy has developed The rapid progress has as in many other areas a certain tendency to accelerate the clinical development and rapidly widen the indications beyond what is justified by the experimental and clinical experience with the newly developed arsenal In this new era of vascular surgery it is specially important to counter act the tendency to exaggerate Perhaps this can best be done by careful collaboration in pre and postoperative assessment and continual fol low up and control of the operative results Moreover it is worth emphasizing that a substantial reduction in hospitalization time for vascular cases has been won by this type of teamwork before hospi talization Many patients with the diagnosis of arteriosclerosis ob literans even the successfully operated receive anticoagulant therapy It is important that this treatment is controlled very carefully and pre ferably by one and the same doctor Diabetes cases with peripheral vascular changes are another example of the advantages of a close collaboration between surgery and medicine To give the patient with stenosing peripheral arterial disease adequate care requires the com bined resources of several different specialized departments and labora tories Through our laboratory for peripheral vascular diseases we hope to contribute to the fulfilment of what the pertinent literature often claims as the need for careful and accurate follow up examinations

SUMMARY

The reason for above and below knee amputations in the lower ex tremity is in over 50 % arteriosclerosis Rehabilitation of the elderly after high amputations is a time consuming and difficult task

One can expect a reduction of the number of high disabled amputees through

1) careful assessment of the circulatory status
2) infection and oedema prophylaxis
3) medical therapy
4) a strict individualization of the amputation level and
5) the use of vascular surgery techniques for reconstruction in suitable cases

Modern reconstructive vascular surgery implies a great gain even for less dramatic circulatory changes such as intermittent claudication. Furthermore the number of cases found suitable for surgery has been increased by the availability of new methods of operation and diagnosis. Analysis of the circulatory status is also important in discrepancies of leg length and in many obscure painful conditions of the lower extremities. There is an immediate need for investigation facilities and hospital beds for the care of peripheral vascular diseases. This is irrespective of whether the surgical treatment falls within the fields of general surgery, orthopaedics or thoracic surgery.

RÉSUMÉ

L'artériosclérose des artères des extrémités inférieurs donne dans plus de 50 % de cas lieu à l'amputation. La réhabilisation des gens âgés après des hautes amputations est une tâche qui est très délicate et difficile et qui nécessite beaucoup du temps.

On peut s'attendre que le nombre des cas invalidisés à cause des amputations ou des complications d'une amputation diminue par

1) Une minutieuse estimation de l'état de la circulation ainsi que la prophylaxie d'infections et d'oedème
2) Traitement médical
3) Un sévère jugement de cas en cas concernant le niveau de l'amputation et par
4) L'exploitation de la technique vasculaire chirurgicale pour la reconstruction dans des cas opportuns

Même pour des troubles de la circulation moins dramatiques comme claudicatio intermittens la chirurgie de reconstruction moderne comporte un grand bénéfice. Au fur et à mesure que des méthodes pour diagnostique et cartographie deviennent accessibles, de même que des

nouvelles méthodes d'opération le nombre des cas favorables pour le traitement chirurgical augmente. Aussi quand il s'agit des différences dans la longueur des jambes et des douleurs diffus dans les extrémités inférieurs l'analyse de l'état des vaisseaux est très importante.

En ajoutant les insuffisances veineuses et lymphogènes dans le projet concernant les soins des maladies vasculaires périphériques on peut constater qu'il existe une très grande nécessité de pouvoir faire des recherches aussi bien d'en avoir des places pour les malades. Il est moins important si le traitement chirurgical soit placé principalement dans le domaine de la chirurgie générale, orthopédique ou thoraco chirurgicale.

ZUSAMMENFASSUNG

Krankheiten und Schäden der Extremitätsarterien sind in über 90 % die Ursache aller Amputationen.

Die Rehabilitation von älteren Patienten nach hohen Amputationen der unteren Extremität ist eine zeitraubende und schwere Aufgabe. Man kann eine Verringerung der Anzahl von Amputationen und von Komplikationen nach Amputationen erwarten, wenn man

1) die Zirkulationsverhältnisse berücksichtigt und damit Infektions und Oedemprophylaxe betreibt
2) internmedizinische Behandlung durchführt (Herz-, Kreislauf- und Stoffwechseltherapie)
3) eine strenge Individualisierung des Amputationsniveaus einhält
4) und sich in geeigneten Fällen der Rekonstruktionschirurgie der Gefässe bedient.

Auch bei weniger dramatischen Zirkulationsstörungen, wie bei claudicatio intermittens, kann die Rekonstruktionschirurgie grossen Gewinn bedeuten. Gemäss der Vertiefung der Einsichten in die Diagnostik und die Operationsmethoden hat sich die Anzahl von für operative Behandlung geeigneten Fällen vergrössert. Die Analyse der Zirkulationsverhältnisse ist auch bei Fällen mit Wachstumsstörungen und unklaren Schmerzzuständen der unteren Extremität von grosser Bedeutung.

Werden die venösen und lymphogenen Insuffizienzen mit in den Aufgabenbereich der Behandlung der peripheren Gefässerkrankungen einbezogen, ergibt sich ein grosses Bedürfnis an Krankenhausplätzen mit Spezialausrüstung. Dabei ist es von geringerer Bedeutung, ob die

chirurgische Behandlung in die allgemeine Chirurgie die orthopadische Chirurgie oder in die Thoraxchirurgie verlegt wird

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ON THE EFFECT OF LAMINECTOMY ON BACK PAIN IN SPONDYLOLISTHESIS

By

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In 1955 *Gill, Manning & White* (1) described a new surgical method for the treatment of spondylolisthesis. According to this method the loose arch of the olisthetic vertebra is extirpated, i.e. laminectomy. In their series of 14 cases the operation produced a very good effect on the back and sciatic pains in 13 (92.8 %) cases, and 6 (42.8 %) patients were symptom free after the operation. Though some investigations have since confirmed the beneficial effect of the operation on the sciatic pain, the effect on the back pain in spondylolisthesis varies from one series to another. Thus in *Gill's* material the back pain disappeared in 11 (78.5 %) of 14 patients operated upon. *King et al.* (2) also found laminectomy to have a favourable effect on the back pain, while *Laurent* (3) found the operation to have no effect at all on the back pain in any of his 26 patients treated by this method.

Gill et al. originally applied the method to eliminate the root symptoms which they found to be due to compression of the nerve roots by the tissue of the pseudarthrosis. But they soon realized that the operation also had an excellent effect on the back pain. They could not explain why the operation gave such a relief of the back pain even though they often found that operation revealed an irritation of the dural sac either because of pressure by an abnormally movable part of the arch or by adhesions between the arch and/or the ligamentum flavum and the dura.

During 1955–1959 a total of 24 patients with spondylolisthesis have been submitted to laminectomy by the method of *Gill et al.* at the Department of Orthopaedics, University Hospital, Lund. The patients had both back pain and sciatic pain, though the clinical picture was usually dominated by one type or the other. Of these patients 22 were refractory to conservative treatment and 2 preferred surgical treatment without

preceding conservative therapy. In an attempt to assess the effect of the operation particularly on the back pain these patients were reviewed. The review included careful inquiry concerning the site, nature, intensity, duration and frequency of the back pain. Furthermore the pains have been placed in relation to occupation, occupational posture etc. On examination of the back notes were made of the configuration of the spine, mobility of the spine and the occurrence of any tenderness, contractures or wasting of the muscles. The review also included a simple neurological examination for any weakness of the abdominal, patellar, achilles and plantar reflexes, the occurrence of paresis in the gluteal, thigh, calf and toe muscles and the occurrence of any muscle atrophy and impaired sensibility.

Of the above mentioned 24 patients 1 could not be traced and 2 were found to have a prolapse of the intervertebral disc for which they were operated upon. These 3 cases were therefore not included in the present analysis. Of the remaining 21 patients 14 were males and 7 females. The patients' ages ranged from 29 to 64, and 12 of them were below 50 (Table 1).

TABLE 1
Patient material

Age in years at time of op.	Males	Females	Total
20–29	0	1	1
30–39	2	2	4
40–49	6	1	7
50–59	4	2	6
60–69	2	1	3
Total	14	7	21

The interval between the operation and the review was 7 months to 4½ years. In 13 cases it was more than 3 years. In 15 (71.4%) cases the spondylolisthesis was situated in the fifth lumbar vertebra and in 6 (28.6%) cases in the fourth lumbar vertebra. No conservatively treated series was collected for comparison.

The patients were classified according to the results of the operation into three groups. Group I consisted of those who had become completely symptom free, group II of those who reported improvement, and group III of those who reported that they felt no better or perhaps even worse after the operation. Only those patients who reported that they

had no back pain at all and who could manage their work without trouble and without a corsette were assigned to group I. Patients who reported that they felt better were assigned to group II.

TABLE 2
Results of operation

Group	Males	Females	Total	
I	5	0	5	23.8
II	5	3	8	38.1
III	3+1	4	8	38.1
Total	14	7	21	100.0

The operation has given complete relief in 5 (23.8 %) of the patients, all males, 2 of them were unskilled labourers doing heavy work. It is difficult to explain why the operation did not produce such good results among the females. As an example of what good results the operation can produce it may be mentioned that 1 of the patients, an unskilled labourer born in 1919, who had had disabling back pain for 6 months, became completely symptom free soon after the operation. Of the remaining patients 8 (38.1 %, 5 males and 3 females) reported a marked improvement after the operation. 4 (3 males and 1 female) of these 8 do not need a corsette, while 4 (2 males and 2 females) sometimes or always wear a corsette. The operation produced no improvement in 7 who must always wear a corsette, and 1 patient reported that he felt even worse after the operation. Examination of the 5 symptom free patients revealed a normal spine except for a slight flattening of the lumbar lordosis and a certain stiffness of the lumbar spine in association with stooping.

Notes were also made of the effect of the operation on the sciatic pain. It was found that the operation has given complete relief of the pain in 11 (52.4 %) patients, partial relief in 6 (28.5 %) and no relief in 4 (19.1 %). Before operation 11 patients had abnormal neurological findings. At the review 6 of these patients had a normalized neurology, 1 showed an improvement, 2 the same picture as before the operation and 2 patients a slight progression of the abnormal neurological findings.

Summarizing, the review shows that the operation has cured the back pain in 5 cases and given considerable relief in 8. The results are not so good as those in *Gill's* series, but excellent compared with those

reported by *Laurent*. If spondylolisthesis does not respond to conservative treatment, laminectomy should be offered. If the operation fails to produce the desired results, operative fusion is indicated.

TABLE 3

Results of operation placed in relation to the ages of the patients

Age in years at time of operation	Males			Females		
	Group I	Group II	Group III	Group I	Group II	Group III
20–29	0	0	0	0	1	0
30–39	2	0	0	0	0	2
40–49	2	3	1	0	1	0
50–59	1	1	2	0	1	1
60–69	0	1	1	0	0	1
Total	5	5	4	0	3	4

— worse after operation

SUMMARY

Twenty one of a total of twenty four patients who underwent laminectomy ad modum *Gill et al.* in 1955–1959 at the Department of Orthopaedics, University Hospital, Lund, were reviewed 1–4 years later. The operation was followed by complete relief of the back pain in 5, by partial relief in 8 and by no relief in 7. 1 patient felt worse after operation.

Patients with spondylolisthetic back pain refractory to conservative treatment should be offered laminectomy. If this operation fails to produce the desired results, operative fusion is indicated.

RÉSUMÉ

21 malades sur 24 chez lesquels a été pratiquée la laminectomie d'après la méthode Gill dans les années 1955–59 à la Clinique Orthopédique de l'Hospital de l'Université de Lund ont été reexaminés 1 à 4 ans plus tard. A la suite de l'opération le malade a été complètement soulagé des douleurs du dos dans 5 cas, partiellement dans 8 et pas du tout dans 7. Un malade se sentait moins bien qu'avant l'opération.

Il convient d'offrir la laminectomie aux malades ayant des douleurs spondylolisthétiques du dos refractaires au traitement conservateur. Si cette opération ne donne pas le resultat souhaité, la fusion operatoire est alors indiquée.

ZUSAMMENFASSUNG

Einundzwanzig aus einer Gesamtzahl von vierundzwanzig Patienten, die einer Laminektomie nach der Methode von Gill et al. in den Jahren 1955–1959 and der orthopedischen Abteilung des Universitätskrankenhauses in Lund unterzogen worden waren, wurden 1–4 Jahre später nachuntersucht. Die Operation war in 5 Fällen von einem vollständigen Verschwinden der Rückensmerzen, in 8 Fällen von einem teilweisen Aufhören und in 7 Fällen von keinerlei Erleichterung gefolgt. 1 Patient fühlte sich schlechter nach der Operation.

Patienten mit spondylolisthetischen Rückschmerzen, die auf konservative Behandlung nicht ansprechen, sollte die Laminektomie angeraten werden. Wenn diese Operation nicht zu den gewünschten Ergebnissen führt, dann ist die Fusion angezeigt.

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CLINICAL OBSERVATIONS ON THE SPINE IN EJECTED PILOTS

By

CARL HIRSCH and ALF NACHEMSON

INTRODUCTION

In co-operation with the Medical Service of the Swedish Royal Air Force an investigation has been made into the condition of the spine in aviators who have rescued themselves by catapult ejection. The investigation was instigated by reports from various sources that even successful ejections not infrequently caused back injuries (Royal Swedish Air Force Report 1952, Montagard & Picamoles 1956, Fabre 1959). In some Air Force circles the stresses to which the spine is exposed have been considered so great that special examinations have been called for. Thus some countries are reported to subject their jet pilots to a preselection roentgenographic examination of the spinal column. Applicants with roentgenographic changes considered to have clinical significance are rejected.

MATERIAL

All 55 pilots who during the period from 1957 through 1960 have made their escape by catapult ejection were included in the investigation. This consisted in eliciting the subjects' history with regard to earlier back trouble and present symptoms, thoracolumbar roentgenography including a tomographic examination, followed by physical check-up in cases where this appeared motivated, carried out at the Orthopaedic Department.

The technical problems connected with type of aircraft, ejection seat or ejection mechanism will be presented separately (Nachemson & Laurell).

The age distribution of the pilots is shown in Table 1. Of the total number of 55, 52 belong to the age group between 20 and 35 years.

TABLE 1

Age distribution of ejected pilots

Age	Number of pilots
20–25	38
26–30	8
31–35	6
36–40	2
41–45	1

VERTEBRAL FRACTURES

Fractures were demonstrated in 14 of the subjects included in this series, in one case dating from before the accident in question. In all cases the injuries involved the vertebral bodies in the form of a more or less severe compression. In 5 cases the injuries affected only one vertebra. Table 2 shows the levels involved in these cases, which on the whole agree with those encountered in other types of accidents.

TABLE 2

Level of single vertebral fractures

Th	5
Th	6
Th	12
L	[illegible]
L	2

Eight patients showed multiple fractures, whose distribution appears from Table 3.

TABLE 3

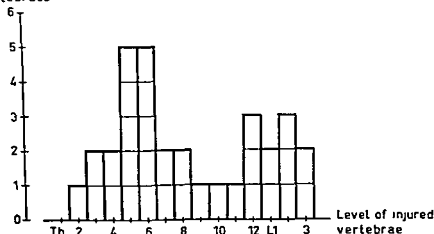
Levels of multiple vertebral fractures

Th 11 Th 12
Th 3 Th 4 Th 5 Th 12 L_1 L L_3
Th 2 Th 3 L_1
Th 6 Th 9 L_1
Th 5 Th 6 Th 7
Th 8 Th 10
Th 4 Th 5 Th 6 Th 8
Th 5 Th 6 Th 7

The fracture incidence and their distribution over the various levels is illustrated by the Table 4.

TABLE 4

Incidence, distribution and level of vertebral fractures



Although back pains were reported by all those who had incurred vertebral fractures, it was remarkable that the symptoms as a rule were fairly mild and that the majority did not consider themselves sufficiently incapacitated to warrant bedrest. Routine roentgenography disclosed 29 of the total number of 32 fractured vertebrae. The cases where tomography was instrumental in establishing the final diagnosis involved only minor injuries. The value of the tomographic examination consisted in a more accurate visualization of the extent of the area involved by the fracture. A fourth of all injuries merely consisted of a central depression of the upper endplate (Fig. 1, Fig. 2, Fig. 3).

ADDITIONAL FINDINGS

As additional findings of the roentgenologic examination, the following were disclosed:

Spondylolisthesis (in all cases involving L 5)	3 cases
Vertebral osteochondritis	4 cases
Schmorl's nodule	4 cases
Old vertebral fracture	1 case
Disk degeneration	1 case
Haemangioma	1 case

(Fig. 4, Fig. 5)

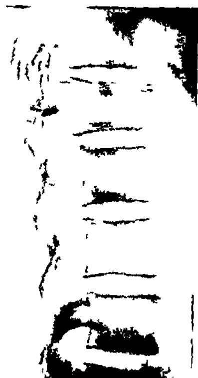


Fig 1
Small compression fracture in a 21 year old pilot Very slight pain for a few days Complete recovery

One of these patients combined changes indicative of Scheuermann's disease with a spondylolisthesis involving L 5 One of the patients with Schmorl's nodules showed multiple fractures of Th 6 Th 9 and L 3 In none of the cases could any indication be found that the disorders dating from before the accident had been aggravated by the stress of the ejection Neither had these pilots experienced any discomfort during their earlier training or service which had made large demands on their physical stamina All of them were able to return to active service immediately following their escape from the wrecked aircraft

FOLLOW UP EXAMINATION

All pilots included in the above series were in the course of the year 1961 given a check up to determine their effectiveness and physical fitness for their work as jet pilots As one of the most recently injured pilots owing to a simultaneously incurred femoral fracture has not yet returned to active service he has been omitted from this report

The period of follow up is set down in Table 5



Fig 9
Tomographs of a 23 year old pilot Th 8 and Th 10 are compressed The deformation of Th 10 was merely in the centre of the vertebral body and was only seen by tomographs

TABLE 5
Follow up period

Period of follow up	Number of cases
3-4 years	8
[illegible] 3 years	11
1-2 years	20
Less than one year	15

All flyers including those with vertebral fractures had returned to active service as jet pilots In one case the period of disability lasted one year due to back pains in the thoracic region This patient was found to have an extremely strong compression of Th 6 and a pronounced gibbus He is now on active service again For the other 11 patients the period of disability ranged from 0 days to 4 months or 2 months on an average With the exception of the one case reported above other injuries incurred simultaneously (Table 6) do not appear to have influenced the period of recovery from the fractures of the vertebrae



Fig 3

Roentgenogram of multiple fractures involving Th 10 L 1 L 2 and L 3 in a 21 year old pilot Three months after injury flying jet again without any symptoms from the back



Fig 4

2[illegible] year old pilot ejected with [illegible]0 g Roentgenogram taken after the rescue showed spondylolisthesis of L 5 with marked ventral displacement of the vertebral body No complaints of back ache either before or after the ejection



Fig 5
Tomogram of the spine from a 2[illegible] year old jet pilot Th 8 and Th 9 were interpreted as vertebral osteochondritis – Scheuermanns disease The picture was taken 2 days after ejection with 20 g No symptoms

TABLE 6
Simultaneously found injuries

Distorsio pedis	4
Luxatio humeri scapularis	1
Fractura femoris	1
Fractura sacri	1
Fractura sterni	1

Tests carried out by the Royal Swedish Air Force have shown that the pilots with back injuries after their recovery and following a training program could tolerate forces of up to 7 g While none of those recovered from back injuries have had to escape from a wrecked *aircraft a second time one of the pilots was found to have an old* vertebral fracture involving Th 7 Like the others he had during the ejection been exposed to approximately 20 g without ill effects on his back There is reason to believe that the healed fractures will successfully withstand the high forces to which they may be exposed in case of a second ejection

Defects in the form of spondylolisthesis, Scheuermann's disease and Schmorl's nodules had neither before nor after the accident caused any pain or other incapacitating symptoms.

As part of the follow-up examination the personnel included in this series were questioned about low back or sciatic pains experienced either before or after the ejection. Nine in all reported to have suffered from short bouts of low back pain or sciatica.

Five pilots reported low back pain before the ejection. Four of them had experienced the same kind of symptoms again after the accident. In their opinion the catapult ejection had not aggravated their earlier symptoms in any way nor had the frequency of the discomfort increased. It appears therefore as though low back pain and sciatica need not be a reason for rejecting a pilot suffering from either of these conditions from active jet service.

Four of the 13 pilots who had incurred fractures reported symptoms suggestive of low back pain. On the whole their discomfort has taken the form of pain brought on by physical exertions other than the type required for their performance as pilots. As a rule the back symptoms have manifested themselves in connection with sports or other more or less civil activities.

SUMMARY

During the period from 1957 through 1960, 55 pilots of the Swedish Royal Air Force have rescued themselves by catapult ejection.

The entire group has formed the subject of an orthopaedic evaluation which included roentgenologic and tomographic examination.

Thirteen of the subjects, or 27 per cent, were found to have incurred vertebral factures. The injuries invariably consisted of compression fractures of the vertebral bodies. In 5 cases the damage involved only one vertebra, whereas 8 cases showed multiple injuries.

Both with regard to the frequency of the injuries and in the distribution of the levels involved, the middle part of the thoracic spine dominates. The injuries have in no case caused neurologic disorders. All injured jet pilots were able to return to active service after a convalescence of 2 months on an average.

Secondary findings disclosed by the roentgenologic examination were spondylolistheses, defects indicative of Scheuermann's disease, Schmorl's nodules, one case of haemangioma, degeneration of a single disk and an old vertebral fracture which had healed. In none of these

cases does the ejection appear to have resulted in symptoms of injuries which might be connected with the above defects.

Five pilots had occasionally experienced low back pain prior to the catapult ejection. In none of these cases were the symptoms aggravated after the ejection.

The injuries incurred as a result of the catapult ejection have been of a mild character. It would seem, therefore, that the technical solution of the ejection escape must be regarded as acceptable considering the seriousness of the situation in which the pilot finds himself on being forced to abandon his aircraft.

ZUSAMMENFASSUNG

Während des Zeitraumes von 1957 bis 1960 haben 55 Piloten der königl. schwedischen Luftwaffe sich mittels Katapultausstossung gerettet.

Die ganze Gruppe wurde einer orthopedischen Auswertung, die auch eine röntgenologische und tomographische Untersuchung mit einschloss, unterzogen.

Dreizehn der Untersuchten oder 27 % hatten Wirbelbrüche erlitten. Die Verletzungen bestanden immer in Kompressionsbrüchen der Wirbelkörper. In 5 Fällen war nur ein Wirbel beschädigt, während 8 Fälle vielfache Verletzungen zeigten.

Sowohl hinsichtlich der Häufigkeit der Verletzungen als auch deren Höhenverteilung herrscht die mittlere Brustwirbelsäule vor. In keinem Fälle haben die Verletzungen neurologische Störungen verursacht. Alle verletzten Düsenflugzeugführer waren im Stande nach einer Rekonvaleszenzzeit von durchschnittlich zwei Monaten zum aktiven Dienst zurück.

Nebenbefunde anlässlich der röntgenologischen Untersuchung waren Spondylolisthese, Veränderungen die auf Scheuermanns Erkrankung hinwiesen, Knorpelknötchen, Hämangiom (ein Fall), Degeneration einer einzelnen Zwischenwirbelscheibe und eine alte geheilte Wirbelfraktur.

In keinem der Fälle scheint die Ausstossung Symptome oder Verletzungen zur Folge gehabt zu haben, die mit den oben erwähnten Defekten in Zusammenhang gebracht werden können.

Fünf Piloten hatten gelegentlich Kreuzschmerzen vor der Katapultausstossung. In keinem der Fälle wurden die Symptome nach der Ausstossung verschlimmert.

Die infolge von Katapultausstossungen entstandenen Verletzungen waren von leichterer Art. Es scheint daher, besonders wenn man den Ernst der Situation in Betrachtung zieht, in der sich der Pilot befindet, wenn er gezwungen ist sein Flugzeug zu verlassen, dass die technische Lösung des Entkommens durch Ausstossung als annehmbar angesehen werden kann.

RÉSUMÉ

Durant la période qui s'est écoulée entre 1957 et 1960, 55 pilotes des forces de l'Aviation Royale suédoise ont utilisé l'éjection par catapulte pour sauver leur vie.

Leur groupe a formé le sujet d'une estimation orthopédique comprenant un examen radiographique et tomographique.

Treize des sujets, soit 27 %, avaient des fractures vertébrales. Les lésions consistaient invariablement en fractures de compression des corps vertébraux. Dans 5 cas, le dommage ne portait que sur une seule vertèbre, alors que dans 8 cas il y avait des lésions multiples.

Tant en ce qui concerne la fréquence de ces lésions que leur distribution dans les niveaux de la colonne vertébrale, c'est la partie centrale des vertèbres dorsales qui est le plus souvent atteinte. Les lésions n'ont dans aucun cas causé des troubles neurologiques. Tous les pilotes souffrants ont été en mesure de reprendre du service actif après une convalescence de deux mois en moyenne.

Parmi les trouvailles secondaires dévoilées par l'examen radiographique, on a constaté des spondylolisthèses, des défectuosités indiquant la maladie de Scheuermann, des nodules de Schmorl, un hémangiome, une dégénération d'un seul disque et une ancienne fracture vertébrale guérie.

Dans aucun de ces cas l'éjection paraît avoir provoqué des symptômes ou des lésions qui puissent être mis en rapport avec les cas précités.

Cinq pilotes avaient occasionnellement ressenti des lombalgies avant l'éjection par catapulte. Dans aucun de ces cas les symptômes se sont trouvées aggravés après l'éjection.

Les lésions dues à l'éjection par catapulte ont eu un caractère bénin. C'est pourquoi il semble que la solution technique du sauvetage par éjection puisse être considérée comme acceptable si l'on tient compte de la gravité de la situation dans laquelle le pilote se trouve lorsqu'il est forcé d'abandonner son avion.

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ON OPERATED HERNIATED LUMBAR DISCS

By

LENNART SODERBERG and SVEN SJÖBERG

Many reports are available on the end results of surgical treatment of herniated discs During the last 5 years however no contributions have been made from Sweden with the exception of the paper by *Knutsson* and *Wiberg* (1958) to which the reader is referred for some comparative data and for references

Material indications for operation myelography—operative findings complications and after treatment

From 1952 to 1956 a total of 241 patients were operated upon for herniated discs at the Orthopaedic Clinic Malmo (Table I)

TABLE I
Patients (241) operated upon for herniated discs in 1952–1956

Age class in years	Male		Female		Total	
	Number		Number			
<20	4	2 5	0	–	4	1 7
20–29	17	10 8	11	13 0	28	11 6
30–39	57	36 4	38	45 3	95	39 4
40–49	53	33 8	25	29 8	78	32 4
50 and above	26	16 5	10	11 9	36	14 9
	157	100 0	84	100 0	241	100 0

The main indication for surgery was generally severe pain for at least 4 weeks without improvement on conservative treatment (usually bed rest) In the event of earlier attacks conservative treatment was sometimes shortened Paresis (severely impaired peroneal function) also widened the range of indications for operation One of the patients had bladder or intestinal paresis before operation

Myelography with Abrodil 20% which was regularly done before operation was positive in 229 (95.4%). In 89% the findings at operation were in full accord with the myelogram. In only 8 (3%) cases was the operative finding uncertain or negative. The myelographic and operative findings are compared in detail in Table II.

TABLE II

Myelographic and operative findings in 241 patients

Positive myelogram 229 patients	Positive op. findings in accord with myelogram	213
	Uncertain op. findings in accord with myelogram	4
	Negative op. findings	2
	Positive op. findings not in accord with myelogram (other disc)	10
Negative myelogram 12 patients	Positive op. finding	10
	Negative op. findings	2

Myelographic examination was never followed by any complications.

When the post-operative course was satisfactory, i.e. rapid abatement of radiating symptoms, the patients were kept in bed for about a week. If the leg pain had not practically disappeared during this time or if complications supervened, bed rest was prolonged.

Post-operative complications occurred in 47 cases (Table III). This incidence may appear high.

TABLE III

Complications in 47 (19 [illegible]) cases

Haematoma with or without wound infection	28
Paresis	10
Thrombosis or embolism	3
Pneumonia	2
Bladder paresis	2
Meningitis	1
Discitis	1
Death	0

The complications were, however, as a rule only transient. Thus, of the largest group "haematoma with or without wound infection" (28 cases) only 4 were kept in hospital longer than those without any complications. Of the 10 patients with impaired peroneal function after operation, 6 reported no persistent symptoms (see questionnaire below) and 4 reported slight paresis at the time of the review. Bladder paresis in 2 lasted only a few days.

The only serious complication was staphylococcal meningitis and septicemia in a 50 year old woman. This case is reported in brief below. The operation passed without complications. No dura injury was seen. Two days after operation the body temperature rose. Antibiotics (streptomycin, penicillin, chlormomycetin) produced no demonstrable effect. *On the ninth day after operation neck stiffness developed and Kernig's sign was positive.* Spine fluid obtained by lumbar puncture contained 2,080 leucocytes and 6,000 erythrocytes. Signs of abscess in the operative field did not appear until 2 weeks after operation. On debridement of the wound abundant pus escaped. Bacteriologic examination showed rich growth of staphylococcus aureus. Culture of spine fluid resulted in growth of staphylococcus aureus which were sensitive only to erythromycin. Erythromycin was therefore given for one month. Repeated blood cultures during this period resulted in active growth of staphylococcus aureus. The body temperature did not return to normal until *2 months after operation. Cerebral symptoms persist.*

One case of "discitis" was observed. The patient had been subfebril after the operation and back pain persisted. Severe cramp-like pain developed in the lumbar region 3 weeks after the operation. Roentgen examination revealed an inflammatory lesion at the level of the fourth lumbar disc (site of operation). Antibiotic therapy was instituted. The patient left hospital 3 months later and after a further 9 months he was healthy. Since then he has been on the whole symptom free.

Post-operative management did not always include physiotherapy and massage. Such treatment was reserved mainly for the patients (136) in whom symptoms of back weakness persisted for a long time after the operation, provided that the radiating symptoms had largely disappeared.

Patients with persistent severe back pain after the operation were treated in the early postoperative course with a plaster jacket (27 cases) or a cloth corsette (32 cases).

REVIEW

All of the 241 patients in 1959 received a questionnaire (Fig. 1). 230 (95 %) of the patients answered the questionnaire.

The further course of sequelae after sciatica has been accounted for in different ways. Many authors compare the state of the patient during the acute stage with that at the review. In the classification of their cases they often employ such terms as "excellent" to denote complete

freedom from symptoms and improved to designate a generally undefined improvement. As to such a painful condition as lumbago-sciatica, which in the acute stage often incapacitates the patient, the term "improved" might however imply that the patient still has fairly considerable persistent symptoms. It would therefore appear more correct to describe the severity and nature of the trouble in those who are not symptom free.

Fig. 1

Questionnaire

1. Have you been free from sciatica and back pain since you returned to work after the operation (if "yes" questions 2–6 need not be answered)?
2. Have you had pain in the back or in the leg or in both?
3. Has the pain occurred occasionally and been of short duration, e.g. after heavy work or in cold weather?
4. Or has the pain been almost permanent but slight?
5. Or has the pain been almost permanent and severe?
6. Have you had a real recurrence (i.e. back pain or sciatica of the same severity as before operation)? If so, how long did the pain last?
7. Have you any persistent numbness of the lower leg or foot? Have you any persistent weakness of the leg, especially of the ankle?
8. Have you been away from work because of symptoms in the back or leg since the operation (state approximately how often and how long)?
9. Has persistent pain since the operation permanently impaired your working capacity. Have you had to change occupation because of such decreased working capacity?
10. Do you think that it was mainly because of the operation
   a) that you have made a complete recovery?
   b) that you feel much better than before the operation?
   c) that you feel worse now than before the operation?

Seventy five (32.5 %) of the patients were completely symptom free after the operation.

The severity and duration of the symptoms in the remainder are given in Table IV, from which it is apparent that 73.3 % (the first 2 groups taken together) were completely or almost completely symptom free after the operation.

TABLE IV

Types of persistent symptoms

	No.	%
Completely symptom free	75	32.5
Occasional slight trouble	94	40.8
Rather constant slight trouble	43	18.7
Rather constant severe trouble	18	8.0

On those that were not completely symptom free the pain was located

Only in the back in	45 patients (19.5 %)
Only in the leg in	10 patients (4.5 %)
In both the leg and the back in	100 patients (43.5 %)

Persistent paresthaesia and numbness of the lower leg and/or foot was reported by 85 (37 %) and a feeling of weakness of the leg and/or foot by 31 (13.5 %).

Recurrence (lumbago and/or sciatica) with pain of the same severity as before the operation were noted in 19 (8 %) patients.

The duration of disability after operation is given in Table V. More than half returned to work within 3 months.

TABLE V

Interval between operation and return to work

		Progressive
>1 month	6.7	6.7
1–2 months	25.6	32.3
2–3	24.5	56.8
3–5	10.5	67.3
5–7	15.8	83.1
<7	9.1	92.2

As to the later course 170 (70 %) had never been away from work because of lumbago-sciatica after the operation, 10 had been away for 1 month, 12 for 1–2 months and 38 (17 %) for more than 2 months.

About one fourth (61 patients) reported that their working capacity was more or less permanently impaired. Ten of these had to take up lighter work after the operation or, if women and married, to stop working out of the house.

As to question 10 in the questionnaire 90 % replied in the affirmative to a) or b). This figure is comparable to figures given for "cured" and "improved" in publications by other authors.

SUMMARY

From 1952 to 1956 a total of 241 patients were operated upon for herniated discs.

Myelography with Abrodil 20 % was positive in 229 (95.4 %).

All of the 241 patients in 1959 received a questionnaire, which was answered by 95 %.

73 % had been completely or almost completely symptom free after the operation.

As to the later course 170 (70 %) had never been away from work because of lumbago sciatica after the operation.

About one fourth reported that their working capacity was more or less permanently impaired.

RESUME

Entre 1952 et 1956 241 malades au total ont ete operes pour hernie discale.

La myelographie avec Abrodil 20 % etait positive dans 229 cas (95.4 %).

En 1959 il a ete envoye a tous les 241 malades un questionnaire auquel il a ete repondu dans 95 % des cas. 73 % ont ete completement ou presque completement liberes de symptomes apres l'operation. 170 (70 %) n'ont jamais ete obliges de s'arreter de travailler pour cause de sciatique lombaire après l'operation.

Un quart environ rapportent que leur capacite de travail est plus ou moins diminuee d'une maniere permanente.

ZUSAMMENFASSUNG

Im Zeitraume 1952 bis 1956 wurde die Gesamtzahl von 241 Patienten wegen Vorfall der Zwischenwirbelscheibe operiert.

Myelographie mit Abrodil 20 % war bei 229 (95.4 %) positiv.

Alle 241 Patienten erhielten im Jahre 1959 einen Fragebogen, der von 95 % beantwortet wurde.

73 % waren vollständig oder fast vollständig beschwerdefrei nach der Operation.

Ungefähr ein Viertel berichteten, dass ihre Arbeitsfähigkeit mehr oder weniger dauernd herabgesetzt war.

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FREQUENCY AND SEX DISTRIBUTION OF CONGENITAL DISLOCATION OF THE HIP AMONG BREECH PRESENTATIONS

By

LARS ANDRÉN

During the nineteenth century it was widely believed that congenital dislocation of the hip was due to injury in association with delivery. It was claimed to be most common among breech presentations and was then ascribed to the manipulations of the obstetrician or midwife.

In an attempt to disprove this assumption *Adams* (1885) published statistics in which he showed that only 7 (15 %) out of 45 infants with dislocation of the hip were breech presentations. But this percentage is higher than what might be expected. In large series the normal frequency of breech presentations is about 3.0 %. The next to study the frequency of breech presentations among children with congenital dislocation of the hip was *Delanglade* (1896). His series consisted of 112 cases with 8 breech presentations. This was more than twice the expected number. In 1905 *Vogel* gave a corresponding frequency of 25 % for a series of about 200 children with the disease. He did not give exact figures. This is a remarkably high frequency but seems to have received but little attention and it is only mentioned parenthetically in *Lorenz's* (1920) monograph on congenital dislocation of the hip.

The first really large series was published by *Isigkeit* in 1928. On the basis of 1785 questionnaires that had been duly filled in and returned he found that 181 (10.2 %) of the children with congenital dislocation of the hip had been breech presentations. Since then several similar series have been published (Table 1).

In a personal series of 36 children with congenital dislocation of the hip diagnosed immediately after birth 11 (4 of 7 boys and 7 of 29

girls) had been delivered in breech presentation. The frequency of breech presentations was 2.6 %.

In large series the congenital dislocation of the hip is 5–6 times more common among females than among males. Thus *Poli* (1937) gave a ratio of ?.7 : 1 and *Idelberger* (1951) 5.4 : 1.

TABLE 1

Frequency of breech presentations in congenital dislocation of the hip

		Total
Adams London 1885	7	45
Delanglade Paris 1896	8	112
Vogel Bonn 1905	25	ca. 900
Isigkeit Sachsen 1928	181	1785
Hoof München 1928	10	66
Scaglietti Bologna 1932	207	2876
Poli Milano 1937	274	7454
Francillon Zürich 1937	[illegible]	196
Marx Charkov 1938	11 %	
Kichelhayn Dresden 1938	same as Vogel	
Bauer Berlin 1940	2[illegible]	116
Storch Berlin 1940	20 %	
v. Haberler Wien 1945	18	60
Klopfer Erlangen 1950	3	10
Czermak Wien 1952	[illegible]	63
Müller & Seddon London 1953	40	95
Nyström & Zilliacus Helsingfors 1956	30	164
Drescher Würzburg 1957	13	123
Record & Edwards Birmingham 1958	27	161
Smith & ...oll Ohio 1959	23	90

TABLE 2

Sex distribution of congenital dislocation of the hip among breech presentations

	Female	Male	Total
Delanglade Paris 1896	6	[illegible]	8
Hoof München 1928	17	8	25
Czermak Wien 1952	18	4	22
Nyström & Zilliacus Helsingfors 1956	13	7	20
Drescher Würzburg 1957	10	9	19
Record & Edwards Birmingham 1958	17	10	[illegible]
Malm. material 1960	7	4	11
Total	88	44	132

The sex distribution of congenital dislocation of the hip among breech presentations has only been studied in few and small series

(Table 2). In practically all collections the ratio between males and females with congenital dislocation of the hip in association with breech presentation is *only twice as common among females as among males*.

It seems that *Record & Edwards* (1958) are the only investigators who have noticed that the sex distribution of congenital dislocation of the hip among breech presentations differs from that among other presentations. They reported breech presentations among 43 % of the boys and among 12 % of the girls in their series of congenital dislocation of the hip. They stated that "the difference between these proportions is much too large to be reasonably attributed to chance", but they offered no explanation for this difference.

It has been discussed whether the dislocation or breech presentation should be regarded as primary, and reasonable arguments have been put forward for both possibilities. Since the dislocation is demonstrable at birth and since the primary cause is elongation of the capsule of the joint, it may be assumed that the breech presentation with long upward pressure against the trochanter is a contributory cause of the elongation of the capsule. Since breech presentations are equally common in both sexes (*Westman* 1931) and since dislocation is about 10 times as common among breech presentations, this difference in the sex distribution supports the view that breech presentation is a strong contributory cause of the dislocation. If congenital dislocation of the hip were the cause of breech presentation, the sex frequency should be the same as among cephalic presentations.

SUMMARY

A survey is given of the frequencies reported for breech presentations in congenital dislocation of the hip.

Congenital dislocation of the hip is about six times as common among females as among males, but among breech presentations with *congenital dislocation of the hip females are only twice as common as males*.

RÉSUMÉ

Il est donné un aperçu de la fréquence rapportée des luxations en arrière dans la dislocation congénitale de la hanche.

La dislocation congénitale de la hanche est à peu près six fois plus commune chez les filles que chez les garçons, mais chez les filles les

luxations en arrière avec dislocation congenitale de la hanche sont seulement deux fois plus courantes que chez les garçons

ZUSAMMENFASSUNG

Eine Übersicht der Häufigkeit von Steisslagen im Zusammenhang mit angeborener Huftverenkung wird gegeben

Die angeborene Huftverenkung findet sich ungefähr sechsmal so haufig bei weiblichen als bei männlichen Kindern aber unter Steiss geburten mit angeborener Huftverrenkung ist die Anzahl der weiblichen Individuen nur zweimal so gross als die der männlichen

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TEARS OF THE POSTERIOR SIDE OF THE KNEE JOINT CAPSULE

Report of two cases

By

Z. SILBERMANN and I. KESSLER

Tears of the knee joint capsule are not known as a separate clinical entity. These cases are included, from a clinical point of view, in the large group of "internal derangements of the knee" and they cannot be diagnosed separately. The diagnosis becomes possible by x-ray examination after filling the knee joint with a contrast medium — arthrography. According to the localisation of the capsular tear, two separate groups can be distinguished:

1) Tears of the capsule on the medial side of the knee.

This finding is well known to those who deal with arthrographies of the knee. Due to the fact that the medial collateral ligament is fused with the joint capsule, tears of this ligament are accompanied by tears of the capsule. In such instances the contrast solution appears as an elongated shadow near medial condyle of the femur. Quite often this picture remains unchanged for a long time, this being an evidence of incomplete healing of the tear (Fig. 1). Lindblom also described similar findings and pointed out that arthrographically it is possible to diagnose the above mentioned tears when extra-articular diffusion of the contrast solution occurs along the medial collateral ligament.

On the lateral side the situation is different. As is known, the lateral ligament is separated from the joint capsule and consequently tears of the ligament are not accompanied by injuries of the capsule.

2) Tears of the capsule on the posterior side of the knee.

This group is the subject of our report. As previously mentioned, those cases are accompanied by unspecified symptoms which clinically cannot be diagnosed. In the arthrography the contrast solution diffuses



Fig 1 A

Case 1 The c ntra t soluti n filled a c st in the p pliteal region and leaked through the pc terior si le of the cap ule diffusing into the soft parts of the upper third f the leg

Fig 1 B

Ca 1 Sec nd arthr graph ix week later The extraarti ular diffusi n of the contra t s luti n i n l nger visil le

extr articularly into the posterior aspect of the knee and scatters between the soft tissues Leoffier described one case in which the contrast solution diffuses as far as the neighbourhood of the ankle

Out of 300 arthrographies of the knee performed in our department we have met two cases of tears of the joint capsule in the posterior aspect of the knee These cases are presented herewith because of their rarity and because of their remarkable response to conservative treatment

C s 1 I M 29 year 11 rt man fell down while jumping in training Th d tail f the mechani m of the injur were n t lear The pati nt c mplaining f p in in hi right knee wa examine l in our department n the f f th ac ident Ther w ten lerne in the area f the me lial fem ral c n lyle m is ffu i n and limitati n f xten i n Plain roentgen gram were neg tive The kne wa imm bili l in a p P ca t f r even da Aft r em al f the t the ffu i n li appe r l but m em nt remaine l painful with limit ti n f xten i n At the ame time ubcutane us haem rrhag n the nt ri r and p t ri r i le f the knee ere l erve l R utine clinical te t w r l ubtful Su g ting a le n f the me li l milunar cartilage w p f rmed an a thr



Fig ? A

Case 2 The contrast solution leaked through the posterior side of the joint capsule into the upper third of the leg

Fig 2 B

Ca e 2 *Eight weeks later after introduction of the contrast solution in the same* po ition the extra articular diffusion is no longer vi ible

graphic examination of the injured knee The contrast solution filled the joint with ut penetration into the triangles In the lateral view the arthrography revealed a popliteal cyst and in the posterolateral side of the knee an escape of the solution outside the capsule diffusing into the soft parts of the leg app 10 cm from the joint line this being an evidence of interrupti n of the j int cap ule continuity (Fig 1 A)

The patient was advised to perform quadriceps drill and bed re t Two week after the injury he was re examined The j int effu ion and the soft ti u haem rrhage were no longer distinguished The patient still compl ained of mil l pain acc mpanying knee movements Physical therapy was continued Six week after the injury a second arthrography was performed The c ntrast soluti n filled the joint without any signs of extra articular diffu ion the site of soluti n escape wa completely closed (Fig 1 B)

Case ? R M 37 years old police fficer wa sent t our department tw la after he prained his right knee while walking At the beginning he felt nl mild pain without any limitation of movement but on the day of his admi i n to us the knee swelled Clinically marked effusi n limitation of the l t

degrees of the extension and flexion and tenderness over the lateral aspect of the joint were observed. Plain roentgen grams were negative. A plaster cast was applied for one week whilst suspecting a lateral semilunar cartilage lesion. After removal of the cast the patient was re-examined. There was a slight effusion in the knee, persistent limitation of movements and tenderness in the lateral aspect of the joint space. In the arthrograph the contrast solution filled the knee without penetration into the triangle of the semilunar cartilages. In the posterior and lateral aspect of the knee the solution escaped into the soft tissue spreading into the upper third of the leg (Fig. 2 A).

The patient was advised to perform quadriceps drill and bed rest. Two weeks later in re-examination marked swelling, tenderness over the lateral aspect of the knee and painful rotation were observed. The patient mentioned also locking of the knee. Suspecting a lesion in the lateral semilunar cartilage in spite of the negative arthrographs we proposed arthrotomy but the patient did not agree to operation. He continued with physical therapy. One month later he felt better still mentioning lockings of the knee but at longer interval. Clinically we observed some atrophy of the quadriceps muscles, tenderness in the lateral and posterior area of the knee without effusion. A second arthrography was performed two months after the injury. The contrast solution filled the joint cavity without penetration into the triangle and without extra-articular diffusion (Fig. 2 B).

On the next examination (ten weeks after the injury) the patient was free of pain and no clinical findings were observed in the injured knee.

COMMENT

The two presented cases were different in their clinical picture but identical arthrographically and in their subsequent courses.

The first case showed unspecified signs of internal derrangement of the knee which did not allow proper diagnosis to be established. The only unusual finding in this case was the soft tissue haemorrhage in the anterior and posterior aspect of the knee which was revealed one week after injury at the removal of the cast. Considering the fact that the haemorrhage did not take place in the second case we cannot conclude whether the haemorrhage originated from the site of the tear of the capsule or from the soft tissue which were injured together with the capsule.

The second case was of more interest because it developed signs of lateral semilunar cartilage lesion. During the clinical course the findings were concentrated on the lateral side of the knee accompanied with locking. Considering that in both arthrographies no penetration of the contrast solution into the lateral triangle took place and the lockings disappeared after healing of the capsule we are inclined to believe that lockings were caused by the incarceration of a part of the ruptured capsule into the joint cavity.

It should be emphasised that the diagnosis in both cases could be established only by arthrographies showing extra-articular diffusion of the contrast solution.

As previously mentioned, the site of the tear was in the posterolateral aspect of the knee capsule. We cannot find any explanation why the tear should take place at this particular side. If in future cases the same findings would appear, one should search whether there is a weak point at the posterior – lateral aspect of the capsule or a special mechanism is the cause of the tear at this location.

In both cases after a relatively short period (six weeks in the first case and eight weeks in the second one) the arthrographies did not show further diffusion of the contrast solution outside the capsule. We consider the negative arthrographies together with the vanishing of the clinical findings as a sign of healing. It seems that during the period of 6–8 weeks a fibrous healing takes place preventing the leakage of the solution outside the joint space.

CONCLUSIONS

1) Tears in the posterior aspect of the knee capsule are considered to be rare. We met only two cases among 300 arthrographies performed after knee injuries.

2) Contrast medium arthrographies are the only means by which such tears could be detected.

3) Diagnosis of such tears is of value to avoid unnecessary operations.

4) Both presented cases became symptom free 6–8 weeks after conservative treatment alone.

RESUME

1) Des dechirures de la partie posterieure de la capsule du genou sont considerees comme etant rares. Nous n'en avons rencontre que 2 cas parmi 300 arthrographies pratiquees apres des lesions du genou.

2) Les arthrographies avec produit de contraste sont le seul moyen de detecter de telles dechirures.

3) Le diagnostic de telles dechirures est important afin d'eviter des operations inutiles.

4) Les deux cas presentes ont ete liberes de symptomes 6 a 8 semaines plus tard uniquement par traitement conservateur.

ZUSAMMENFASSUNG

1) Risse in der Ruckseite der Kniegelenkskapsel werden als selten angesehen. Wir fanden unter 300 Arthrographien, die nach Knieschaden vorgenommen worden waren, nur 2 Falle.

2) Kontrastarthrographien geben die einzige Moglichkeit solche Risse zu entdecken.

3) Die Diagnose solcher Zerreissungen ist wertvoll um unnotige Operationen zu vermeiden.

4) Beide vorgestellen Falle wurden 6–8 Wochen nach konservativer Behandlung symptomfrei.

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FROM THE DEPARTMENT OF ORTHOPAEDIC SURGERY, UNIVERSITY OF MALAYA IN SINGAPORE (HEAD: ANDERS KARLÉN, M.D.)

ON CYSTIC TUBERCULOSIS OF BONE

By

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It is to be expected in a place like Singapore where the rate of tuberculosis is still high that there will be a big variation in the individual resistance to this disease and consequently the clinical and radiological appearances will vary as well. Cystic tuberculosis in bones is best regarded as either an expression of a high resistance already present where the lesion is walled off early, or of resistance rapidly acquired after that period in the spread of the disease which *Wallgren* (1948) has called the allergic phase and where the disease shows up as a condition called multiple pseudocystic tuberculosis of bones. That the disease normally has a strong tendency to invade the neighbourhood is clearly shown by *Cholmeley* (1939), who studied the results of treatment in the pre-antibiotic period 1927–1937 of 55 cases with tuberculous lesions close to the hipjoint. 43 cases were treated conservatively and 12 with excision. Only 3 escaped with a mobile joint, 2 treated conservatively and 1 with excision. That surgery of localised lesions also under the pre-antibiotic time could be successful has been shown by *Ratliff* (1957), who has described 3 cases of tuberculosis of the femoral neck in childhood treated with drainage and curettage and which all had full movement in the hip joint when seen 10 years later. The introduction of the antituberculous drugs has of course made radical surgical treatment much safer.

In this article 3 cases of solitary tuberculous lesions and 3 cases of multiple pseudocystic tuberculosis of bones will be presented. All are young children from 2½ to 4 years of age and they are all Chinese.

The solitary cysts were preoperatively diagnosed as Brodie's abscess. This diagnosis was based on the history combined with the radiological picture which showed a cystic lesion well bordered with a sclerotic zone and in one case containing a sequestrum. Sclerosis which means osteogenesis in the neighbourhood of a tuberculous lesion occurs, as *Girdle-*



Fig 1



Fig 2

Fig 1 Well defined cyst in the medial lower part of the neck of right femur
Fig 2 Caput and collum bigger than on the left side (Coxa magna) No subluxation or destruction Time of observation 5¼ years

stone & Somerville (1952) has put it seldom except at a distance in space or time from an active tuberculous focus In these cases two of which occurred in the femoral neck and one in the lower tibial metaphysis the length of the history is 5–12 months and the osteogenesis is in the immediate vicinity of the lesion

Case 1 Male 2½ years of age

Pain and limp for 12 months Fever the night before symptoms started Better after 10 days but limping persisted all the time Since 1 month relapse of pain and also night-cries

12 8 1953 Limping on the right side Movements in the right hipjoint restricted in all directions

Blood BSR 37 mm Hb 102 % T R 4 75 T W 10 500

Urine Alb + P C 1–2 R B C 1–2

Mantoux positive 1 10 000

Chest X Ray Right hilum is sligthly heavy with some calcifications

X Ray of right hipjoint Well defined cyst in medial lower part of collum Epiphysis slightly irregular Joint space normal (Fig 1)

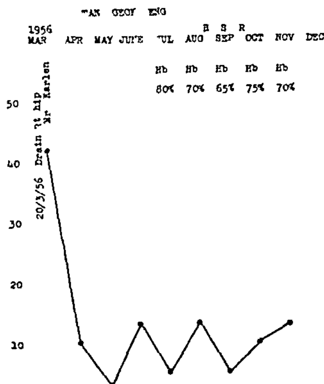
17 9 1953 *Curettage* Performed through lateral approach

Biopsy Positive for tuberculosis

Postoperatively treated with streptomycin PAS and INH for 6 months combined with fixation 2 months in hip spica and 4 months on abduction frame This period of immobilisation was followed by 11 months in a leather support

Last seen 5½ years after operation There was then no limp or any complaints Full movements in the hipjoint The X Ray showed that

Fig 3
BSR chart in Case 2 Good reaction to treatment The same applies to Case 1 and 3



collum and caput were bigger than on the left side (Coxa magna) but no subluxation or destruction (Fig 2)

Case 2 Female 4 years of age
Had a fall 6 months ago Limping on the right side for 5–6 months
12 3 1956 General condition good Walks with a limp The right hip is in flexion—abduction—external rotation contracture Some muscle wasting
BSR 43 mm (Fig 3)
Chest X Ray Primary complex
X Ray of the right hipjoint Cystic area in medial lower part of collum with sequestrum (Fig 4)
20.3 1956 Curettage + Sequestrectomy through lateral approach
Biopsy Positive for tuberculosis



Fig 4



Fig 5

Fig 4 Cystic area in the medial lower part of collum of the right femur with big sequestrum

Fig 5 Cystic disappeared Head and neck enlarged and in valgus position (Coxa valga magna) Time of observation 3 years

Postoperatively treated with streptomycin PAS and INH for 6 months and fixation for 5 months (3 months in hip spica and 2 months on abduction frame)

Last seen three years after operation *No complaints Fit and well* Excellent range of movements The X Ray of the right hipjoint showed that the cyst had practically disappeared Head and neck enlarged and in valgus position (Coxa valga magna) but no subluxation or destruction (Fig 5)

Case 3 Male 4 years of age

Swelling and pain in the right ankle 6 months ago Subsided after 10 days and the boy was gradually able to walk again Swelling recurred off and on more marked 10 days before admission No fever or cough

30 4 1957 *General condition good* Marked swelling of the right ankle fluctuant in the upper part

Blood B S R 47 mm Hb 82 % T R 4 03 T W 10 100

Urine Alb + *P C* 2–3

Chest X Ray Primary complex

X Ray of the right tibia Big cystic area in the medial half of the lower metaphysis juxta epiphyseal Fibula thinned through pressure (Fig 6)

3 5 1957 *Curettage* through posterior approach

Biopsy Positive for tuberculosis Postoperatively treated with streptomycin PAS and INH for 6 months combined with fixation (plaster of paris 7 months and leather garter 6 months)



Fig 6 *Fig 7*

Fig 6 Big cystic area in the medial half of lower end of right tibia Justa epiphyseal Fibula thinned through pressure

Fig 7 Cyst disappeared Time of observation 1¾ years

Last seen 1¾ years after operation No complaints Fit and well Walking well without limp Hardly any swelling Full movements The X Ray of the lower end of tibia showed complete healing with disappearance of the cyst (Fig 7) [1]

The remaining three cases are thought to belong to the type of cystic lesions called multiple pseudo cystic tuberculosis of bones This name was suggested by *Komins* (1952) to avoid confusion of certain sarcoid lesions of bone It applies to characteristic multiple cystlike bone lesions seen in tuberculosis of children it differentiates these lesions from those due to sarcoidosis which *Jungling* (1920) had grouped under the term Osteitis multiplex tuberculosa cystica

Multiple pseudo-cystic tuberculosis of bone is uncommon *Young & Clinton Thomas* (1955) collected 29 cases from the literature and added one of their own *Murray* (1954) has pointed out the following criteria

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[1] Since this article was written a further 3 cases of single cysts have been seen
1 in the femoral neck
1 in lower end of femur and
1 in upper end of tibia
The follow up time is however too short hence these have not been included



Fig 11 a



Fig 11 b

Fig 11 a Destruction of upper part of left scapula and of posterior part of 6th left rib

Fig 11 b No bony lesion in left scapula The 6th left rib regenerated

Case 5 Female 4 years of age

At age of 1½ years there was small swelling on left lower malar bone growing slowly Admitted to hospital Gland taken out Later treated by general practitioner—"a small piece of bone is said to have been taken out 1½ years ago pus started to discharge through a sinus in outer corner of left eye No fever Swelling of both forearms for 1 month Cough for 2–3 years

9 8 1956 General condition fair Apathetic Left malar region swollen not tender Discharging sinus at outer corner of lower left eyelid Left forearm swollen on the upper half on the radial side The swelling is diffuse hard not tender Fluctuant swelling over posterior aspect of upper part of right forearm *Big fluctuant swelling in left fossa iliaca*

Blood BSR 69 mm Hb 54 % T R 2 6 T W 6 300 (Fig 10)

Chest X Ray No pulmonary lesion

Skeletal X Ray

1 Erosion of D 11–12 with destruction of disc

2 *Posterior part of the left 6th rib destroyed*

3 Destruction of upper part of left scapula (Fig 11 a)

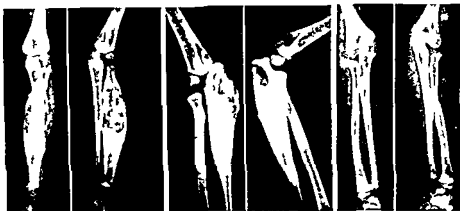


Fig 12 a *Fig 12 b*

Fig 12 a General enlargement of left radius with cystic destruction in midpart plus sclerosis in the distal part Cystic destruction in upper end of right ulna and in olecranon

Fig 12 b Slight angulation of left radius in the midpart No deformity of the upper part of right ulna Time of observation 2 years

4 General enlargement of left radius with cystic destruction in mid part + sclerosis in distal part (Fig 12 a)

5 Cystic destruction in upper part of right ulna + olecranon (Fig 12 a)

21 8 1956 *Curettage* of left radius and right ulna
16 11 1956 Drainage of psoas abscess on left side
27 11 1956 Sequestrectomy of right ulna
12 3 1957 Excision of sinus + drainage of left scapula

Biopsy Positive for tuberculosis from right ulna left radius psoas abscess and left scapula

Treated with streptomycin PAS and INH for six months and as umbrella on further operations Short periods of fixation in plaster of paris after the operations

Last seen two years after last operation General condition good No sinuses Full movement in both elbows and shoulders No swelling Spine quite mobile without tenderness

B S R 15 mm The X Ray of the skeletal system showed

Scapula and facial bones No bony lesion detected (Fig 11 b)

Regeneration of the 6th left rib



Fig 13
Case 6 on admission Thin and emaciated Note the swelling in the right side of the *forehead on both hands and on upper part of right tibia*





Fig 14 *Fig 15*

Fig 14 Pott's disease with destruction of D7–D9
Fig 15 Marked cystic lesions in 6th and 7th right and 6 left rib

Moderate collapse of body D 11 with some narrowing of disc below it Complete recalcification

Slight angulation in the midpart of left radius

No bony lesion in right ulna (Fig 12 b)

Case 6 Male 4 years of age

Not well for two years One week before admission there was fever sweating and coughing Poor appetite

25 5 1955 Very thin and emaciated Prominent swelling on the right frontal region of skull (Fig 13)



Fig 16
Well demarcated cystic lesion in the frontal region

Extremities Swelling at proximal end of right ulna and fusiform swellings of the 2nd and 4th right metacarpal Same type of swelling over proximal end of left ulna and left second metacarpal Some bowing forwards of right tibia with a localised swelling in the middle third

Blood B S R 62 mm Hb 49 % T R 2 4 T W 7 100
Calcium 11 mgm% phosphates 5 3 mgm% K T negative
Urine Alb + P C 3–4 R B C 2–3
Mantoux pos 1 100
Chest X Ray Primary tuberculosis
Skeletal X Ray

1 Kyphosis in mid dorsal spine due to partial destruction of D 7 and D 9 and total destruction of D 8 (Fig 14)
2 Ribs Cystic lesions with expansion in the 6th and 7th rib on the right side and 6th rib on the left side (Fig 15)
3 Skull Well demarcated cystic lesion in the frontal region (Fig 16)
4 Forearms Well demarcated cystic lesion in left olecranon multiple cystic lesions in upper part of right forearm and olecranon surrounded by sclerosis Small cystic lesions also seen in the lower lateral part of right humerus (Fig 17)
5 Hands Partial destruction combined with sclerosis of both 2nd metacarpals and 4th right metacarpal bone
6 Right tibia and fibula Big cystic lesions in upper and middle part of tibia with some expansion of the bone (Fig 18) The mid

Fig 17 *Fig 18*

Fig 17 The lesions in both ulnae lower end of right humerus
Fig 18 Cystic lesions in both fibulae and right tibia

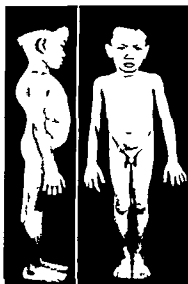


Fig 19
Patient s condition when last seen 3 years and 4 months after operation



Fig 20 a



Fig 20 b



Fig 20 c



Fig 20 d



Fig 20 e

Figs 21 a e

Pott s disease healed with good recalcification No lesions detected in ribs skull forearms of tibia and fibulae

part of right fibula is expanded by multiple cystic lesions surrounded by sclerosis

7 Left fibula Expansion of the midpart of the bone In the centre is a cystic lesion surrounded by sclerosis

3 6 1955 *Curettage* of right ulna

Biopsy positive for tuberculosis

Postoperatively treated with streptomycin PAS and INH for 6 months plus immobilisation in box and on frame for 10 months

Last seen 3 years and 4 months after operation Fit and well (Fig 19) Full movements in elbows hips and knees No sinuses The X Ray examination of skeleton showed a well healed Pott s disease D 7—8-9 The rest of the skeleton was normal (Figs 20 a-c)

SUMMARY

Two types of cystic appearance of bone tuberculosis are described in all 6 cases Three of them are single metaphyseal or metaphyseal epiphyseal cysts well defined and clinically impossible to differentiate from other cystic lesions The remaining 3 are thought to belong to the type of tuberculous skeletal manifestation called Multiple Pseudo Cystic Tuberculosis of Bone

RESUME

Deux types d apparence kystique de tuberculose osseuse sont decrits en tout 6 cas Trois d entre eux sont de simples kystes metaphysaires ou metaphysaires epiphysaires bien definis et qu il est impossible clinique ment de differencier d autres lesions kystiques On pense que les trois autres appartiennent au type de la manifestation squelettique appelee « tuberculose osseuse pseudokystique multiple »

ZUSAMMENFASSUNG

Zwei Typen der zystischen Form der Knochentuberkulose insgesamt 6 Falle werden beschrieben Drei davon sind einzelne gut abgegrenzte metaphysare oder meta epiphysare Zysten die klinisch unmoglich von anderen zystischen Schädigungen unterschieden werden konnen Die übrigen drei scheinen zu jener Type von Skelettuberkulose zu gehoren die als Multiple pseudozystische Knochentuberkulose bezeichnet wird

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PROCEEDINGS OF THE NORDISK ORTOPEDISK FORENINGS 30TH ASSEMBLY IN OSLO

JUNE 1960

The meeting of the Scandinavian Orthopaedic Association was held in Oslo under the presidency of J. Alvik

INNERVATION AND CENTRAL NERVOUS CONTROL OF SKELETAL MUSCLES

by *Jan Jansen Jr* (Oslo)

In the following we shall briefly discuss certain aspects of the nervous control of skeletal muscles in the light of some recent investigations. The first problem is whether striated muscle obeys the "all or none law", i.e. whether a stimulus strong enough to produce a contraction of a muscle fibre always causes maximum contraction. The other is whether rapid phasic contractions and slow tonic contractions are produced by different muscle fibres. New evidences have to a certain extent clarified these problems. In addition a brief survey of the main reflex connections of afferent impulses from the muscles shall be attempted.

In primitive vertebrates the existence of two fundamentally different kinds of extrafusal muscle fibres is now well established (Kuffler & Williams 1953 a, b). The so-called slow fibres are characterized by their histological appearance, multiple innervation and motor endplates of the "en grappe" type (Krüger 1952) as well as by their slow and graded contractions, slow relaxation and inability to conduct action potentials. Motor nerve impulses produce fairly long lasting depolarization of the slow muscle fibres. Later impulses and activity in other nerve fibres may add to the depolarization and the resulting contractions depend upon the degree of depolarization of the muscle fibre. Thus slow muscle fibres do not obey the "all or none law".

On the other hand the twitch muscle fibres have motor end plates of the "en plaque" type. Motor nerve impulses produce a localized depolarization of the muscle fibre in the end plate region. The end plate potential initiates an action potential which is propagated along the muscle fibre and acts as a trigger for the contractile mechanism. The twitch fibre contraction and relaxation are fairly rapid processes. Under physiological conditions the twitch fibres behave according to the "all or none law".

There is thus in the lower vertebrates a group of muscle fibres characterized by slow graded contractions. In the frog these are found particularly in postural muscle (Kuffler & Vaughan Williams 1953 b), whereas the twitch muscle fibres are primarily concerned with phasic movements.

As regards the next problem, whether similar slow muscle fibres exist in mammals and man some controversy still remains. It has however with modern physiological methods not been possible to find slow extrafusal muscle fibres with graded contractions in mammals. As far as we know extrafusal muscle fibres of mammals

are all of the twitch type with contractions triggered by action potentials Thus the problem of maintained tonic contractions is entirely different in higher vertebrates and in order to elucidate it we have to look at the sense organs in the muscles and their reflexes

Two well defined groups of receptors exist in skeletal muscle the muscle spindles and the Golgi tendon organs Of these the muscle spindles are by far the most complicated They consist of specialized encapsulated thin muscle fibres intrafusal muscle fibres with afferent nerve terminals in their central region Two groups of afferent nerve fibres enter the muscle spindle some thick fibres ending in the so called primary ending and some thinner fibres which supply the secondary ending Little is known about the functional significance of the latter group

The receptors in the muscle spindles are excited by passive stretch of the muscle and their discharge frequency increases with increasing extension During extrafusal muscular contraction however the muscle spindles pause as they are in parallel with the extrafusal muscle fibres and this provides a means for their identification in physiological experiments On the other hand contraction of the intrafusal muscle fibres will increase the tension in the central receptor region of the spindles and thereby the frequency of afferent impulses (see Granit 1955 for references) Being in parallel with the extrafusal muscle fibres the spindles will record the length of the muscle whereas the tendon organ which are in series with the main muscle will record its tension

The activity of the intrafusal muscle fibres and thus the afferent spindle discharge is controlled by the central nervous system through their motor innervation They are supplied by a particular group of motor fibres which have been called the gamma fibres on account of their small diameter Of considerable importance is the question of the nature of contraction in the intrafusal muscle fibres Is it of the twitch or the tonic variety described above? This problem can not be regarded as settled Recently Eyzaguirre (1960) has succeeded in recording action potentials from intrafusal muscle fibres in the cat and this is good evidence for the existence of an intrafusal twitch system Other observations however suggest intrafusal contractions of the slow type (Kuffler Hunt & Quilliam 1951) The recent histological work of Boyd (1959) is of considerable interest in this connection He describes two types of intrafusal muscle fibres the one with localized and the other with diffuse motor endplates reminding one of the twitch and slow muscle fibres in lower vertebrates Thus there is possibly a histological substrate for both rapid and slow intrafusal contractions

The possible importance of this may best be inferred from a study of the reflex effect of the muscle proprioceptors The investigation of these problems has to a certain extent been aided by the fact that the afferent fibres from one type of receptors tend to be of fairly uniform diameter The afferent fibres in the dorsal root can be classified into different groups according to their diameter and these groups have been called I (20–12 μ) II (12–4 μ) and III (4–1 μ) (Lloyd 1943 a) The afferent impulses from the primary ending of the muscle spindle and from the Golgi tendon organs run in group I fibres whereas the impulses from the secondary ending of the spindle run in group II fibres As nerve fibres of different diameter have different physiological properties (conduction velocity threshold to electrical stimulation resistance to mechanical pressure and local anesthetics) it has to some extent been possible to study the reflex effects of the different afferents separately

It is now well established that the thickest fibres in the dorsal roots (group 1 a) originating in the primary endings of the muscle spindles make direct excitatory synaptic connections with motoneurons in the anterior horn belonging to the same muscle. This loop constitutes the pathway for the stretch reflex (Lloyd 1943 b). The excitatory stretch impulses from the muscle receptors will reflexly tend to keep the muscle at the same length. More recent investigations show that the excitatory effect of group 1 a afferent impulses is more widespread than formerly believed. Not only does it affect the motoneurons of the muscle itself and its synergists but muscles operating neighbouring joints may also be influenced in a fairly complicated pattern which has been related to the action of the different muscles in integrated movements (Eccles & Lundberg 1959).

The group I afferent impulses furthermore has powerful inhibitory effects on the antagonistic muscles. The inhibitory action is probably transmitted through interneurons in the spinal cord (see Eccles 1957 for references). Thus the group 1 a afferents with excitatory effects on synergistic and inhibitory effects on antagonistic muscles is one of the mechanisms for Sherrington's important principle of reciprocal innervation of the skeletal muscles.

The main reflex effect of the impulses from the Golgi tendon organs (group 1 b) in extensor muscles appears to be inhibition of extensors (autogenetic inhibition) and reciprocal facilitation of flexor muscles (Granit 1955). The effects are mediated via polysynaptic pathways. The autogenetic inhibition has been regarded as a protective reflex preventing possible damage from excessive tension in the muscles. Furthermore the group 1 b afferents presumably take part in the integration of movements for instance in walking (Eccles & Lundberg 1959).

As regards the reflex effects of the two last groups of afferent fibres from the muscles (groups II and III) the picture is at present far from complete. That is partly because the receptors of the group III fibres have not been identified. The group II fibres supply the secondary endings of the muscle spindles. On electrical stimulation the group II and III fibres exert excitatory effects on flexor and inhibitory effects on extensor motoneurons. This action is in accordance with the flexor reflex and the effects are elicited from flexor as well as from extensor motor nerves (Eccles & Lundberg 1959).

After this brief summary of the reflex effects of afferent impulses from the skeletal muscles the mechanism of sustained tonic contractions shall again be considered. The muscle spindles and their efferent innervation are of particular importance in this connection. Even during resting conditions there appears to be a steady tonic discharge in the gamma motoneurons innervating the intrafusal muscle fibres (for references see Granit 1955). The resulting intrafusal contraction will produce a steady stream of afferent impulses through the group 1 a afferents with excitatory action on the corresponding alpha motoneurons innervating the extrafusal muscle fibres.

For some time it has been known that the extrafusal muscle fibres of many mammals are differentiated in two types, so called red and white fibres (Denny-Brown 1929). Both however have the characteristics of the twitch fibre described above. Even so the contraction of the red muscle fibres are fairly slow and they are found predominantly in postural muscles. From the extensive investigations of Granit and collaborators it now appears that these "tonic" extrafusal muscles fibres are innervated by a particular group of spinal motoneurons characterized by their ability

to discharge tonically in response to maintained group I a afferent impulses (Granit Phillips Skoglund & Steg 1957) Here is thus a system of tonically firing gamma motoneurons possibly causing slow intrafusal contractions and thereby maintained afferent impulses acting particularly on motoneurons innervating postural muscles a system remarkably adapted for maintenance of reflex tone

The activity of the gamma motoneurons is to a large extent influenced by activity in the suprasegmental parts of the central nervous system (Granit & Kaada 1952) This can be studied particularly well in the decerebrate animals in which the gamma motoneurons apparently are released from descending inhibition The resulting hyperactivity in the gamma motoneurons and spindle loop contributes to the remarkable increase in tone in the extensor muscles seen in such preparations and known as decerebrate rigidity Once the spindle loop is broken for instance by section of the dorsal roots the rigidity disappears as shown by Sherrington (1898) but the increased gamma activity persists (Granit 1955) As suggested by Granit it appears likely that a similar gamma release may be of considerable importance in spastic states so often encountered in the neurological clinic

Even from this brief and simplified summary it should be clear that our knowledge of the nervous control of movements is still far from complete It can safely be assumed however that the continuing experimental study of these problems will prove to be of increasing value also for the practical problems involved in the diagnosis and treatment of disorders of motility and tone

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MUSCLE FUNCTION FOLLOWING TENDON TRANSFER

by *Knud Jansen* and *Kaare Nyholm* (Copenhagen)

In an attempt to analyse the problems related to muscle coordination following tendon transfer we have obtained a certain impression of the influence of the centrally regulating mechanisms on the functional result by electromyographic recordings from different muscles in varying combination We shall only quote a few observations from our work.

The experiments were performed with a Disa electromyograph with 3 channels one of which was connected to an integrator allowing a comparison of the activity from 2 different muscles or musclegroups With surface electrodes placed longitudinally above the middle of the muscle belly activity was recorded during isolated joint movements and as far as the lower extremities are concerned in some cases during walking

The present experiments were made on 28 patients with different tendon transfers 11 elbow paralysis of which 10 were operated ad modum Steindler and 1 ad modum Clark 6 quadriceps plasties 3 tendon transfers ad modum McCarroll Schwartzmann and 8 with various tendon transfers on the foot

The 10 Steindler plasties were performed on 8 patients with polio sequelae and in 2 cases on patients with traumatic lesion of the brachial plexus

In our recordings we decided to differentiate between the 3 main muscles groups on the forearm as apart from the flexor and extensor group we distinguished the radial extensor group which we find has special interest with respect to its synergic function in elbow bending

Activity was recorded during movements of the wrist with the foream in horizontal position of rest Moreover elbow flexion was illustrated by the various forms of technique which Steindler patients emplo

A clinical investigation of elbow flexion distinguished 3 a excellent with a flexion strength of about 4 All 3 were characterised by a normal strength in the forearm muscles before the operation 5 had varying strength about 3 and in a single case was found reinnervation of the normal elbow flexors

In isolated wrist movements (extension and flexion) the pattern of activity was found to be uniform in all patients and does not differ from findings in normal controlpatient With greater strength an increasing dominance of the integrated activity was found of the flexing and extending muscle groups with slight activity

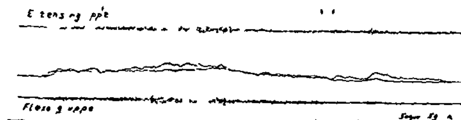


Fig 1

Electromyographic recording of activity during elbow flexion extension movement in a 10 year old girl operated according to Steindler (normal findings)

of the antagonistic group (Hand and fingers were as far as possible held in a relaxed position during the movements) During the total flexion extension movement in the elbow from 150 -60 and back to the position of rest the activity relationship between the two groups was found to be uniform in 5 out of 6 cases (fig 1) Beside the strong and increasing activity of the flexor group we found the same condition in the extensor group in which the strength achieved may influence the elbow joint to an increasing extent during flexion This argues in favour of using this strength in cases of elbow paralysis by simultaneously transferring the common head of the extensors especially in those cases where the radial extensors are strong and can assist in stabilizing the wrist These integrated activity curves were found to be identical at elbow flexion during different positions of the lower arm and hand

Thus the varying forms of hand and forearm position do not alter the activity curves

The activity of the radial extensor group shows the same increase in activity as the 2 other groups and so works synergistically with the flexors as far as the elbow flexion is concerned

The typical finding in these patients is a strong innervation of both forearm flexors and extensors and radial extensors and antagonistic activity corresponding to the wrist is graduated during elbow flexion

One single case differed considerably from the other since the activity of the extensor group was found to be slight by comparison with that of the flexor group (fig 2) and moreover this was very constant throughout the whole movement The patient was operated on bilaterally and the mild extensor activity was identical on both sides corresponding to the activity in a moderate wrist extension On examination he came out with the strange fact that he could carry out the movement without preceding intense cerebral concentration This was the only case in which we could demonstrate a reduced activity of the extensor group i e a partial segregation of the flexor and extensor actions

The patient who revealed reinnervation of his normal elbow flexors was also found to be particularly interesting since in spite of clinically slight flexor ability in the albow he was not capable of innervating the biceps and the transposed fore arm muscles at the same time but employed exclusively his reinnervated normal elbow flexors

Before the Steindler operation wrist arthrodesis was undertaken together with 3

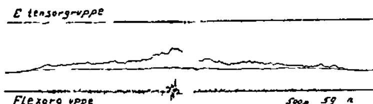


Fig 2
Electromyographic rec rding of activity during ell ow flexion extension movement in an 18 year old male operated according to Steindler (bilaterall) Note the slight extensor activity Reduction of acti ity of the extensor group was found to be identical on both sides

tendon transfers on the hand with muscles from the transposed flexor group and a distinct rise in activity of the flexor group was noted w th the corresponding finger movements

Thus there were 2 possibilities of explaining the absent flexor innervation in elbow flexing Either the patient was not capable of activating the 2 groups of elbow flexors simultaneousl or the tendon transfers ha l offered the flexor group an alternative and it had chosen the function of the han l

In 8 patients with tendon transfers on the foot 7 cases underwent transposition of one of the peroneal muscles which gave a uniform result in the simultaneous recording of activity of the tw muscle since it was not possible in any of the ca es to diff rentiate the activities of the two mu cles This is in accordance with our findings in the qua lriceps plastie in which a single muscle was functionally transp se l from a gr up with a comm n function to a group with reverse or diverging function In these con lition the transpo ed muscle seeks functional acceptance in the new group without altering its relation hip to the old one In onl one case we saw a total reversal of an individually transposed muscle and this wa the til ialis anteri r m ed to the heel tendon

Respecting our 6 patients with quadriceps plastics and alsc 3 patients operated ad m dum McCarr ll Schwartzmann the bservati n perio l is still too h rt to draw up the final results but in 5 ca es inclu ling ? operated ad m dum McCarr ll Schwartzmann increa ing activity wa dem nstrated during knee extension while activity during knee flexi n was unchanged—a result which corresponds with find ing in ingle ten l n transfer on the f t

One patient wa especially int re ting ince she c nstantly c mplaine l of walking tr ul le when starting to walk foll wing a McCarroll Schwartzmann peration 5 years earlier After a m ment s concentration she wa able t re ume walking with out troul le Thi patient had certain p ints of similarity with the ab ve menti ned St in ller patient Electr myograph sh wed str ng activity of the emitend n u b th d ring knee flexing an l knee extending When recording during walking igns were foun l of pre ention of activity of the emitendino us but no pha e d splacement

Finally we wi h to rep rt briefly the only one f the p tients with qua lricep plastics in whom all the medial flexors and the bicep were transpo e l and who

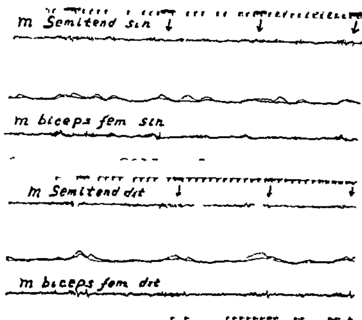


Fig 3

Electromyographic recording of walking in a girl aged 12 with right sided quadriceps plasty (all the hamstring muscles transposed to the quadriceps tendon) — *Top* Left lower extremity (control)—marking left heel contact —*Bottom* Right lower extremity—marking right heel contact *Note the cessation of activity of the transposed* muscles in the stance phase and the accumulation of activity last in the swing phase

clearly differed from the other patients by total absence of activity during isolated knee flexion and with strong activity during knee extension

The patient was a girl aged 14 who underwent the above mentioned tendon transfer 5 years earlier The patient had fully capable glutaeus maximus muscles and gastrocnemius muscles On the right side all the medial muscles and the biceps were transposed to the quadriceps tendon When comparing the two lower extremities during walking a powerful knee extension—almost hyperextension—was observed on the right side at the conclusion of the swing phase If the medial side of the right femur was watched a brief powerful muscle contraction was to be seen corresponding to the transposed semiflexors in the same phase

When comparing the electromyograms from the semitendinosus and the biceps of the femur on the two sides (fig 3) normal phase activity is found corresponding to the conclusion of the swing phase and the whole of the stance phase on the left side (the non operated side) On the right side a total cessation of activity is found during the stance phase while a powerful and brief accumulation of activity occur of the muscles at the conclusion of the swing phase There seems therefore to be a complete cessation of muscle function in the stance phase after tendon transfer *From symmetrical recording of the glutaeus maximus and gastrocnemius medialis*

no change is found in the localization phase but with the medial gastroenemius increasing activity is found on the right side in the stance phase The latter muscle seems thus to have strengthened its stabilizing function on the knee joint in the stance phase

With the aid of film and electromyograms a total reversal of muscle function is demonstrated in a 14 year old girl with quadriceps plasty in whom a whole functionally and anatomically correlated group (all the semiflexors) was transposed to the quadriceps tendon

Conclusion

Our present observations have revealed that selective tendon transfers give rise to considerably greater problems of function than the anatomical conditions seem to indicate This is most likely due to the fact that the interventions undertaken have a penetrating influence on fundamental innervation patterns after which new balance must be established solely through central cerebral regulation

IMPROVEMENT OF MUSCLE STRENGTH AFTER ISOMETRIC MAXIMAL CONTRACTIONS

by *Harald Brodin* (Lund, Sweden)

41 test individuals aged 20–23 years practised for 6 seconds daily the isometric and maximal contraction of the abductor muscle of the fifth finger of their best hand for 5 days of the week After 8 weeks exercise an increase in the abduction strength was obtained of 214 ± 47 gf i e 20 %

Insignificant increase in abduction strength in the little finger of the other hand was also observed ("crossed education") A control series of 41 test individuals of approximately equal age obtained after 8 weeks a slight increase in strength in the abduction function of both little fingers

Statistical analysis showed that the increase in strength in the trained group was statistically certain even when taking into consideration the slight but general increase of strength in the control series

Conclusion

The training method tested gave such small results that it can hardly be recommended for clinical use The discrepancy between these findings and previously published laboratory results of the training method were not discussed

EXPERIENCE WITH TENDON TRANSPOSITIONS IN POLIO SEQUELAE IN CHILDREN

by *Lis Zachariae* (Copenhagen)

Introduction

Tendon transposition operations in polio sequelae have been carried out for many years but have always been a much discussed problem Where adult individuals are concerned it is agreed that it is best to combine the tendon transposition with an arthrodesis If however asymmetrical paralyses are involved in younger children

arthrodesis cannot be performed and in such cases a well planned tendon transposition can many times prevent the arrival of the severe deformities which occur during growth

The principle in all tendon transposition is that the deforming factor must be removed and also that this tendon is to be used to restore as normal a balance as possible

At the Orthopaedic Hospital Copenhagen Dept II we have operated on a number of younger children from the polio epidemic of 1952 with asymmetric paralysis in the feet The establishment of indications and methods of operation were so uniform that it may be of interest to record the results since in this way one may possibly obtain lines of guidance for future principles of treatment

Series and methods

The series consists of 58 children 24 boys and 34 girls whose age distribution appears in fig 1 and who had polio in 1952 They all had asymmetric paralyses in the lower legs and feet with initial deformities as sequelae *Tendon transposition* operations were performed 2 years after the acute stage since the pareses are considered to be stationary at this time The period from the operation to the re examination is 5–6 years

Fig 1

Age distribution of 58 children operated on for polio sequelae by tendon transposition

Age at op	No of children
5 years	38
5–9 years	20
Total	58

6 of these children were operated on bilaterally

Fig 2

Tendon transpositions undertaken on 64 feet with polio sequelae

Type of tendon transposition	No
Tib ant or post moved laterally	9
Peroneals and/or tib post moved to heel tendon	5
Toe extensors moved to tib ant and/or peronacus brev to tib post	28
Peronaeuslong moved to the dorsum pedis	2
Total of feet	64

In fig 2 a survey is given of the type of tendon transposition The total result of the whole series has not been recorded since the deformities are so different in type instead each group is estimated individually

From fig 3 it will be seen that more than half the patient did not terminal treatment with the primary operation but had to be operated on again

In 24 supplementary operations had to be performed for the same deformity 1 of these were reinsertions and 3 were lengthening of the heel tendon and in several of the remainder supplementary transpositions which ought to have been undertaken at the 1st operation e g transposition of lateral muscles to the heel

cord With greater experience one can undoubtedly almost avoid this form of re operation More serious complications which demand reoperation are new deformities which arise as a consequence of the primary tendon transposition there are 14 of these In 3 a Z position of the 1st toe was involved following transposition of the tibialis anterior and here tran position of the ext hall longus to the 1st meta tarsal was undertaken In the remainder all cases involved overcorrection in varus following tendon transpositions in valgus feet

Fig 3
Number of reoperations on 64 feet treated with tendon transposition

	Number of feet
Reoperation for same deformity	24
Reoperation for different deformity	14
Total	38

By reoperation for a different deformity is meant a deformity arising after the primary operation

The series is divided into 3 major and 1 minor group fig 2 In each group the deformities and the tendon transpositions undertaken are of mainl the same type although it must be made clear that there is an infinite number of variations in the mutual interplay of the vari us muscles In establishing indications for the operations an assessment was attempted not only of the degree of the pareses but also of the static and loading f the foot and the function of the small foot muscles was also taken int consideration Only muscles which were sufficient for the task were moved since it is calculated that the lose some strength on removal and before the tendon transposition operations the existing deformities have been cor rected as far as possible e g by redressements or operations e g., lengthening of the heel tendon

Concerning the calcaneus feet the result is differentiated in different qualities while all other feet are onl clas ed as g d or bad B p or re ult is meant un changed or increasing deformity of the same kind as before the operation or over c rrections and by good result is meant that the balance of the foot is restored and that the d formity is bviou ly impr ved

Varus deformity

This deformity arises from weakness of the peroneal muscles and/or the extensor digit longus Often an equinus position is found at the same time and greater or lesser cavus according to the strength of the tibialis posterior but drop foot is rarely found although dependent on the strength of the tibialis anterior Here the perati n were transpo ition of the tibiali anteri r or p terior to the lateral b rder f the fo t depending on which of the 2 muscles is e timated to be the mo t important d forming factor

In many ca es the tendon transpo itions mu t be combined with lengthening of the heel cord and/or moving the extensor hall longus to the 1st met tarsal When tran po ing the til po t it is conducted through a hole ut in the intero se u mem brane The tran po ed tend n is fixed by means of drillholes in the os ut oi l bone l pull-out wire The results appear in Fig 4

Fig 4

Results of tendon transposition with varus position in 9 feet with polio sequelae

Type of tendon transposition	Results	
	good	poor
Tib post transposed laterally	3	1
Tib ant transposed laterally	4	1
Total	7	2

Supplementary to the tendon transpositions 3 interventions of heel cord lengthening were undertaken and 3 Jones

In all 9 of these operations were undertaken 7 of which were undertaken 7 of which were excellent in 3 of these a Jones operation was performed and in 3 a lengthening of the heel cord 2 were poor the one where the tib post was transposed has constant varus position and in addition drop foot probably because the tib post tendon was too short and could not reach down to the lateral border of the foot so that it was ineffective An attempt was made to improve the result by moving the toe flexors to the peronaeus longus but without effect In the second case the tib ant was moved but the tendon came loose on being fixed and on re operation it could not reach down then the tib post was transposed and the varus position was prevented but there is now very considerable drop foot

Conclusion

In varus position owing to polio sequelae in feet transposition of the tib ant or post to the lateral border of the foot shows good results

In many cases the operation must be supplemented by lengthening of the heel cord or by the Jones operation

Valgus Deformity

This deformity arises through weakness of the tibialis anterior and/or tibialis posterior Often an equinus position is found at the same time and varying degrees of cavus or planus according to the strength of the tibialis posterior Fig 5 shows the results of the tendon transpositions undertaken

With paresis of the tib ant but with an intact tib post transposition of the extensor hall longus is carried out to the site of insertion of the tibialis anterior or of all long toe extensors to the same site In all 13 of these operations were undertaken 6 with all toe extensors all of which were good and 7 with the extensor hall longus alone 4 of which were good and 3 poor Of the three poor had such pronounced drop foot that although the peronaeus longus was transposed to the dorsum pedis this had no effect on the drop foot and at the follow up this was found to be due to heel cord tightness The last case had pareses of the tib post therefore transplantation was not sufficient In pareses of the tib post but with an intact tib anterior transposition of the peronaeus brevis to the tib posterior tendon was undertaken. This operation was undertaken in 5 cases all of which were poor In 4 the transplant had no effect and the deformity was unchanged in 1 there was overcorrection in varus In pareses of both tib anterior and posterior a combination of these 2 operations was undertaken i e transposition of the per

naeus brevis to the tib post and of toe extensors to the tib ant either in one or several sessions

Fig 5

Results of tendon transposition in valgus postion of ?8 feet with polio sequelae

Type of tendon transposition	Results	
	good	poor
Ext hall long → tib ant	4	3
Ext dig long → tib ant	6	0
Peron br → tib post		5
Combination of these	2	8
Total of feet	1?	16

This was performed in 10 feet 4 of which had overcorrection in cavus varus these were very difficult to correct again they were operated on several times later and only 1 achieved a fair result In 4 no effect was obtained from the transplants and deformity remained unchanged Only 2 were good but in both no function was gained from the transposed peroneaeus brevis and only the transposed toe extensors now function and give a good result

Conclusion

In valgus position owing to polio sequelae in feet the transposition of toe extensors to tib anterior produces good results while the transposition of the peronaeus brevis to the tib posterior in all cases gives poor results since this transposition if it works produces overcorrection in varus In many cases heel cord lengthening must be undertaken simultaneously with tendon transposition

Calcaneous deformity

This deformity arises from weakness of the triceps The operation is transposition of the peronaeus longus and brevis and/or the tib posterior to the heel tendon

Fig 6

Results of tendon transpositions in calcaneus posit on in ?5 feet with polio sequelae

Type of tendon transposition	
Peron and/or tib post to heel cord	
Osseous deformity	
unchanged	20
increased	3
decreased	?
Triceps sufficient	7
Triceps insufficient	18
Complications	
Deformity	5
Instability	1?

The results appear in fig 6

It will be seen that the essential effect of tendon transpositions is that the osseous heel deformity does not arise so that a later arthrodesis is facilitated

Out of 25 cases only 3 experienced an increase in the osseous deformity following tendon transposition 20 were unchanged and in 2 the deformity was reduced In only 7 cases did the triceps remain sufficient in strength after the operation and in these cases the muscle was not O before the operation The reason for this is presumably that the transposed muscles are not in themselves sufficient in strength to function as triceps The most important complication is instability of the foot joint and subtalar joint when the lateral muscles have been transposed this is found in almost half of the cases In moreover 5 cases secondary malpositions arose owing to an intact tib posterior In 2 heel tendon tightness arose after the operation

Conclusion

In the calcaneus position arising from polio sequelae the transportation of the peronaeus and tib posterior to the heel cord can prevent the osseous heel deformity from developing The triceps becomes however seldom sufficient in strength and in about ¼ of the cases instability occurs in the foot One must always transplant all the lateral muscles at the same time

Drop foot deformity

This deformity arises from weakness of the tib anterior and toe extensors The operation practised in transposition of the peronaeus longus to the dorsum pedis i e to the insertion of tib ant This was only performed in 2 cases both of which were poor Both had calcaneus position because the triceps was too weak.

Overall conclusion

These series show that certain tendon transpositions may be of value in preventing foot deformities from occurring in children with assymmetrical pareses following polio In a number of cases an existing deformity may disappear following the operation It is important to plan carefully the tendon transposition and as far as possible to correct contractions i e equinus before or during the operation

One tendon transposition namely peronaeus brevis to tib posterior gives in all cases poor results and must be avoided

Fig 7
Results of Grice s operation on 15 feet with polio sequelae and tendon transpositions undertaken

Type of deformity		Results	
plano valgus	9	good	10
calcaneo valgus	3	poor	5
varus	3		

With many of the patients it is necessary later to undertake arthrodesis operation In 15 cases of the recorded series it was found necessary in the course of the

observation period to undertake a Grice operation i.e. the insertion of bone chips in the sinus tarsi (Fig. 7). Out of these 15 there were 10 good results with clinical subtalar fixation and correction of the malposition. But only 8 showed radiological healing of the bone chips. The remaining 5 were poor since there is no subtalar fixation neither clinically nor radiologically and the malposition has increased.

The poor results are found especially in strongly paralytic feet irrespective of which malposition was primarily involved.

DISCUSSION

H. Nilsonne (Stockholm)

Tendon transplantations in polio have their given area of indication very limited however, especially when a patient of a growing age is concerned. One can never estimate by means of a muscle test the forces which may influence during growth the deformity of the leg and of the arm.

The transplantations are, however, of no small value in securing the best dynamics for the extremity during growth.

A polio child should never be operated on for tendon transplantations, however, without emphasising to the parents that it is probably a palliative and temporary operation and that it is very probable that on puberty or afterwards a skeletal operation with a permanent value will become necessary. By means of the first operation a better starting point will have been established.

MUSCLE FUNCTION OF TRANSPLANTED FLEXOR MUSCLES IN THE THIGH IN PERIPHERAL PARALYSIS OF EXTENSOR MUSCLES

by *Kaare Haug* (Stavern, Norway)

Summary

A survey is given of earlier opinions of the range of indications for transplantation of thigh flexors in paralysis of the quadriceps in residual poliomyelitis. The theoretical basis for the principle of transposition is to be sought in the static equilibrium of the body. Important details of the operation are pointed out and the surgical technique used at Kysthospitalet ved Stavern is described.

The material which covered a 10 year period consisted of 20 patients on whom a total of 23 operations were performed. Thirteen patients (15 operations) were examined by the author with simple clinical methods.

During the observation period the range of contraction increased in 4 cases and decreased in 5.

The changed functional conditions of the transposed muscles did not appear to influence their functional capacity as judged by observation of the patient while climbing stairs.

The postoperative improvements and undesired side effects (sequelae) of the operation are presented in detail. An observed postoperative decrease in genu (valgum) and of lumbar lordosis is emphasized.

The results obtained were comparable to those reported by other authors for they were satisfactory in 94 ... In one case the operation gave no relief except elimination of a knee joint contracture of 10

In 2 cases the good results of operation were spoilt in one case by a supracondylar femoral fracture and in the other by forced passive flexion during parturition In the latter case extension was afterwards improved by reconstruction of the ruptured lig patellae

STUDIES OF ULNAR NERVE INJURIES BY MEANS OF A NEW SPECIAL ERGOMETER

by *Lennart Mannerfelt* (Boras Sweden)

The difficulties in the way of grading objectively an injury to the ulnar nerve are obvious Great interest lies in discovering whether regressive or progressive tendencies are taking place Certain problems here must be solved as

1 How does motor regeneration occur after an ideal suture to the ulnar nerve?
2 Which muscle or which groups of muscles regenerate as the first?
3 How does a certain contusion to the ulnar nerve infuence motor functions within the area?

Objective measurements are required to follow up such problems Partial injuries must also be followed up and one must be able to evaluate which muscle groups are affected by paresis and which are not

The need for a special ergometer to determine these questions has long been present Certainly in some studies (*Lewey Kuhn* and *Juditsky* 1947 and *Neuman* 1949) the question was taken up but since no sizable series has been presented there is reason to believe that the method admitted of doubt

For some years now the need for objective registration of ulnar nerve injuries in my work has clamoured for a solution The orthodox squeeze ergometer" has proved not delicate enough and can in no way make detailed distinctions for evaluating nerve injuries in the ulnar region *Moberg* (1948) indicated a more correct method when he introduced his special ergometer to measure the pinch grip" However possibilities of evaluating questions of detail within the ulnar region were lacking since only the pinch grip" was examined with his ergometer As this special grip consists of a summation of the majority of the components involved in the thumbindex finger grip it therefore follows that not only the ulnar nerve is concerned In reality both the flexor pollicis longus and the flexor profundus to the index finger are engaged here and also extensor pollicis brevis together with the first dorsal interosseous muscle

In order to cultivate a movement governed by the ulnar nerve it showed to be necessary to find out how the adductor pollicis works It now appears that the adductor works in two ways mainly Where the thumb moves parallel with the volar surface down towards the top of the third metacarpal head a purely ulnar adduction is found. A palmar adduction movement occurs where the thumb follows a path at right angles to its former path i e from the abducted position at right angle towards the metacarpal plane II-V and completing its movement towards the volar aspect of the index finger

In order to grade this last movement objectively a bridge was first built on which the thumb could glide at right angles towards the metacarpal plane II V Attached weights calculated the objectively measurable force The bridge was clumsy and proved to be unsuitable for exact work cf Fig 1

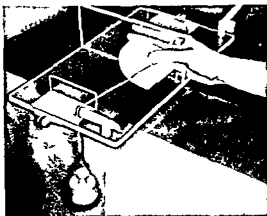


Fig 1

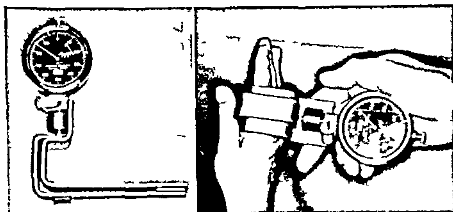


Fig ?

A simple and reliable method had to be evolved therefore and with the ergometer now constructed I believe that my aim has been achieved. Briefl the present ergometer consists of two steel springs which are pressed together This pressure is projected ont a preci ion instrument (Metron Dial Indicator) on which e ch interval repre ents 1/100 mm of movement

This ergometer is not intende l for individual exhibitions of strength but w rks as a preci ion inst ument with great powers of discrimination

By mean f the e g met r the f llowing muscles g verned by the ulnar nerve can be measure l an l di tinguish d

1 Adductor I llici cf Fig ?
? Abductor digiti q inti
3 First d r l int u mu cl
4 Other intero e u mu cle

(Furthermore both the "pinch grip" and some of the hands other intrinsic functions can be measured as abductor pollicis brevis and opponens pollicis)

By means of the mentioned ergometer a fairly large normal series has now been measured in order to ascertain normal values In addition a *comprehensive investigation* into ulnar nerve injuries is being carried out both those operated on by nerve suture and those not operated on This last group consists of partial injuries not suitable for surgical intervention

The ergometer has proved of great value With the instrument we now have a method of demonstrating in an *objective* manner whether *regressive* or *progressive* tendencies exist in a certain nerve injury in the ulnar region In questions of compensation cases the ergometer can without doubt be shown to be of use

EXPERIMENTAL EVALUATION OF THE HYPOTHESIS OF LIGAMENTO MUSCULAR PROTECTIVE REFLEXES

by *B Stener* (Gothenburg Sweden)

The hypothesis of ligamento-muscular protective reflexes put forward in the literature was tested on 49 decerebrate cats and 35 unanaesthetized subjects using the medial collateral ligament of the knee joint

In cat a method was developed for effecting a large increase in the ligament's tension without appreciably damaging its *innervation* during the preparatory dissection Three different methods were used for studying the effect on the motor side of increasing the tension *in* the ligament myography electromyography and monosynaptic testing All muscles able to oppose an increase *in* tension in the ligament were tested With none of the methods and in none of the muscles was it possible to detect any reflex motor effects in response to the increase *in* tension in the ligament although control reflexes could be elicited That the absence of reflex motor effects was not due to absence of afferent discharge could be shown by recording impulses from the medial and posterior articular nerves

In man the ligament's tension was increased *in* a natural way by forcibly trying to abduct the tibia on the femur The effect of increasing the tension *in* the ligament on the activity in muscles capable of opposing abduction at the joint was studied by electromyography No reflex motor effects *ascribable* to stimulation of ligamentary receptors were *observed*

Taken together the results in cat and man provide strong reasons to doubt the existence of a protective muscular reflex originating in tension receptors located in ligaments

Detailed accounts of these experiments on cat and man have been published in Acta Physiologica Scandinavica Vol 48 Suppl 166

ELECTROMYOGRAPHY IN DIAGNOSIS OF LUMBAR ROOT COMPRESSION SYNDROME

by *Bertil Knutsson* (Lund Sweden)

TRANSPOSITION OF THE TRACTUS ILIO TIBIALIS TO THE PATELLA IN THE LATE STAGE OF POLIOMYELITIS

by *Erik B Riska* (Helsingfors)

Material

The treatment of paralysis of the quadriceps muscle and some deformities of the lower limb in residual poliomyelitis is reviewed on the basis of 56 follow up cases of transposition of the tractus ilio tibialis to the patella The patients were operated on from 1943–1959 in the Ortopaedic Hospital of the Invalid Foundation of Finland

With regard to age at the onset of the disease the largest group (23 cases) is made up of the youngest patients between six months and 3 years old The intervening time between the onset of disease and an operation was less than 4 years in about half of the cases The period of observation had an average duration of about [illegible] years it was 11–12 years in the largest group (19 cases) of patients subjected to follow up examinations

Indications for operation

Indications for operation were paralysis of the quadriceps muscle with consequent limping and loss of stability causing knee buckling and falling or hand to knee walking fixed deformities of the lower extremities following contracture of the tractus ilio tibialis with its allied structures (probably the greatest deforming factor in lower limb involvement in residual poliomyelitis genu valgum knee flexion deformity and external torsion of the tibia flexion and abduction contractures of the hip) Some of the patients had been forced to make prolonged use of braces or crutches

Treatment

In 41 cases the tractus ilio tibialis was detached laterally in its axial direction and severed distally from its attachment to the lateral condyle of the tibia after which the tractus was rotated 180 on its axis and fastened to the patella In the other 15 cases the tractus was entirely detached that is laterally as well as ventrally in its axial direction and distally from its attachment It was transposed in its plane and fastened to the patella (motion picture shown) After operation the extremity was immobilized for 3 4 weeks with the knee joint at maximum extension and the hip joint in slight flexion In most cases physiotherapy was commenced prior to operation with the correction of fixed deformities and one week after operation with exercises of the tensor muscle training of the knee joint and walking exercises followed after termination of the period of immobilization

Results

Dividing the results [illegible] the clinical s[illegible] w[illegible] n ted increased extension force of the knee joint in 40 [illegible] out of 56 (71 4 [illegible]) with higher stability of the knee joint in 43 cases ([illegible] 6 8 [illegible]) completely corrected or reduced faulty position w[illegible] recorded in [illegible] 1 ca[illegible] out of 30 ([illegible] 0 0 [illegible]) in 15 cases out of 2[illegible] (68 1 [illegible]) the patient was able t[illegible] di ca d [illegible] [illegible] ace [illegible] ru he 11 patients were unchanged In [illegible] e en of these cases certain err[illegible] in operating technique were responsible for the failure In two case the in[illegible] ti n [illegible] [illegible] th n mi ju lge l and in tw[illegible] cases [illegible]ome other dis case was t [illegible] 11 m[illegible]

There were no cases of impairment in the present series i e no patient was compelled to resort to braces or crutches on account of the operation No faulty position of the knee joint had resulted from the operation and faulty position established preoperatively had not increased in any case

Conclusion

In consideration of the present results and of the previous reports which give rather high percentages of impaired cases (e g recurvatum of the knee lateral dislocation of the patella lateral instability of the knee) in treatment of quadriceps pareses by transposition of the hamstrings this transposition of the tractus ilio tibialis to the patella and utilization of the m tensor fasciae latae (which is mostly spared by the paralysis) is thought to be a suitable and justified method of operation in the treatment of quadriceps pareses and certain deformities of the lower extremities caused by contracture of the tractus ilio tibialis subsequent to poliomyelitis

(This paper will later be published in a complete form)

MEASURING MUSCLE STRENGTH AS AN AID TO JUDGING THE RESULT OF TENDON TRANSPOSITION

by *A Möllerud* and *A Bent en* (Oslo)

In measuring muscle strength before and after tendon transposition the aim was to judge the result objectively and thus plantar and dorsal flexion power of the foot was measured following tendon transpositions around the ankle joint Since the majority of tendon transpositions are performed on children who on follow up should normally have grown and become stronger it was necessary to secure a normal series for purposes of comparison This normal series was obtained by measuring strength in schoolchildren aged 10 14 years Thus quite a good correlation is gained between body weight and strength especially plantar flexion strength On comparing the objectively measured improvement in strength after tendon transposition and the clinical assessment of the result it will be found that the latter on the whole gives rather too favourable a picture of the result

DISCUSSION

H Støren (Stavern Norway)

I should like to thank Dr Haug for the conscientious investigation he has made into our series of muscle transpositions of the thigh flexors in poliomyelitis I should like to put forward a few supplementary remarks It must be clearly realised that the results are dependent on

1 The strength and vitality of the flexor muscles which are transposed It occurs very often that the muscles which are at the disposal of poliomyelitis are not full sound The carry the consequences of paresis

If the results are recorded as a total percentage as was done although with reservations by Dr Haug and earlier by Schwartzman and others then this says nothing about the series one has had to deal with—and does not give a correct opinion on the effectiveness of the operative procedure chosen

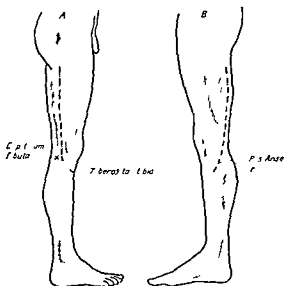


Fig 1

A Through a lateral incision the anterior surface of the patella is exposed and the biceps and tractus iliotibialis are transposed

B Through a medial incision the medial hamstrings are transposed

The results must be recorded in groups in relation to the condition of the hamstrings employed

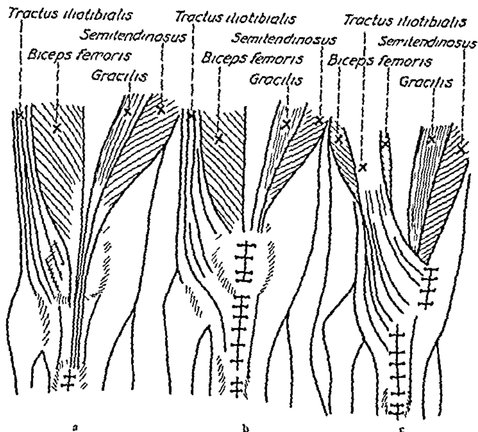
2 The results are also dependent on the technique employed and the method of operation The well known and obvious rules for muscle transpositions are

1 that the innervation is not harmed
2 that the muscles are given a correct course from origin to the fixation site
3 that the fixation is trustworthy intraossal during suitable tension
4 that the immobilisation is long enough We take 8 weeks
5 that there is muscle training of the hamstrings before and after transposition

On operation I employ the 2 long incisions which are illustrated and which B low Hansen used These afford a good view of the muscles depressed and permit the fulfilment of the above mentioned conditions better than any of the other incisions I know

An important point is that the lig infrapatellare in poliomyelitis pareses is often slack and atrophic The tendons of the medial thigh muscles must therefore also be secured to the tuberositas of the tibia as well as the patella— so that they are simultaneously embedded in the lig infrapatellar The biceps tendon is too short for this It does not extend further than to the lower edge of the patella (fig 2 a)

If the fascia lata is preserved—this is used so that the iliotibial tract is detached behind and rotated around its longitudinal axis and sutured above the remaining transposed muscle of the patella It works then as a knee joint extensor and the operation works simultaneously against the polio myelitic valgus position of the knee (fig 2 a b c) Examples of this are to be seen in the material presented



Figs 2 a and b

Fig 2 a Biceps embedded in the patella groove Gracilis and semitendinosus in the patella the infra patellar lig and tibial tub *Fig 2 b* Periosteum and the divided infrapatellar lig sutured over

Fig 2 c

Ili tibial tract turned 180 around its axis and sutured above the other muscle tendons

S *Friberg* (Stockholm)

Dr Mollerud said that he had transplanted the tendon of the posterior tibial muscle in a number of cases I presume that it was passed through the interosseous membrane in the cases under discussion

At the Orthopaedic department of Karolinska Institut we have for many years been interested in the transplantation of tendons and formerly we also transplanted the tendon of the posterior tibial muscle For a couple of years in the beginning of the last decade one of my colleagues advocated transposition of the tendon of the posterior tibial muscle in pes equino varus deformities The results were not satisfactory I have with time become more and more reluctant to transplant this tendon also for other indications In contrast to a number of other foot tendons it cannot

be transposed without considerable loss of strength and as a rule notable loss of stability of the foot

O Mogens Hansen (Copenhagen)

Erik Moberg (Gothenburg)

THE AXIS OF THE ANKLE JOINT AND ITS IMPORTANCE IN SUBTALAR ARTHRODESIS

by *Thomas Wyller* (Oslo)

The direction of the axis of the ankle joint is described somewhat variously in the literature but generally it is described as almost entirely transverse in relation to the sagittal plane of the normal foot

Barnett Napier and Hicks examined the axis of the ankle joint in greater detail Barnett and Napier examined 152 cartilage-covered talus bones and found that the medial profile of the trochlea consists of an anterior arc with a small radius and a posterior arc with a large radius while the lateral profile forms a single arc with a mean radius (Fig 1)

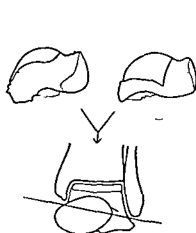


Fig 1 A

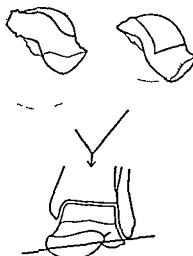


Fig 1 B

Figs 1 A and B

The medial profile of the trochlea tali is composed of a ventral curve with a small radius and a dorsal curve with a large radius The lateral profile consists of a single curve of medium sized radius Movements of the foot dorsally from the O position therefore occur about an axis that is higher medially than laterally (1 A) and plantar movements from assumption of the O position occur about an axis that is lower medially than laterally (1 B) For clarity the lateral side of (the left) talus is given in mirror reflection (Barnett & Napier 1952 Reproduced from the Journal of Anatomy with kind permission of the editors and of the authors)

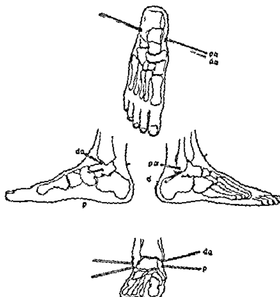


Fig 2

Axes of ankle joint p a = axis of plantar movement for assumption of O position d a = axis of movement for dorsal movement for assumption of O position (Hicks 1953 Reproduced from the Journal of Anatomy with kind permission of the editors and the author)

In moving the foot dorsally to the O position (both in the dorsal and plantar direction in this dorsal area of movement) it is the anterior part of the trochlea with the sharp medial arc which is in contact with the tibia From this Barnett and Napier concluded that these movements must occur around an axis which is higher medially than laterally Fig 1 a The reverse is the case with movements plantar of the O position (both in the plantar and dorsal direction in this plantar area of movement) now it is the posterior part of the trochlea with the slack medial arc which is in contact with the tibia These movements must therefore occur around an axis which is lower medially than laterally Fig 1 b

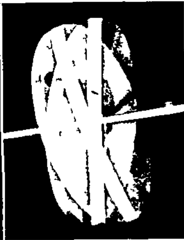
The oblique position of both axes in relation to the horizontal plane varies amongst individuals

The extent of the variation in breadth is not stated directly in Barnett and Napier's work but from graphs it appears that the obliquity of the axis for the plantar area varied from 0° to 16° and that the obliquity of the axis for the dorsal area in selected groups totalling 83 bones varied from 0° to 14°

Hicks examined the movements in the ankle joint by means of 5 presumably normal preparations The soft tissue of the preparations was preserved up to 4 cms above the ankle joint The movements were produced by pulling on the tendon both with and without weight bearing by the foot

Hicks also found 2 axes one for the dorsal and another for the plantar area of movement The axes had the same direction of inclination relative to the horizontal plane as Barnett and Napier had calculated Moreover Hicks found that both axes





F g 3 A *Fig 3 B*

Figs 3 A and B

The sagittal plane of the foot may be regarded as a round disc with the ankle joint in the centre and the axis of the joint eccentric (3 A) On movement al ut its axis the disc will be thrown from one side to another like a poorly mounted wheel (3 B)

passed obliquely in relation to the frontal plane of the fo t since the medial end of both axes pointed somewhat ventrall On Hick illustration (Fig ?) I have measured the horizontal projection of the divergence of the axes from the frontal plane to 14 and 17 (The frontal plane is thought to be at right angles to the longitudinal axis of the foot On Fig 2 the horizontal projection of the foot is shown in slight abduction s the oblique position of the ankle axes appears larger still)

As clinical landmarks Hicks st tes that the axis of the dorsal area of movement passes from a point 1½ cms in front of the tip f the medial malleolus to a point ½ cm bel w the tip of the lateral malleolus and that the axis of the plantar area pa es from a p int 1½ cms in front of the tip of the medial malle lus and 1 cm below it t a point ½ cm above the tip f the lateral malle lus

The fact that the ankle axis pa ses obliquely instead of at right angles to the sagittal plane of the foot means that the foot moves in the ankle joint like a badly mounted wheel If we imagine the sagittal plane to be a round disc with the ankle joint as its centre and the ankle axis mounted obliquely the disc will wobble from side to si le in its movements around the axis Fig 3 If we regard the tip of the foot we call this swerve abduction/a lduction if we regard the heel (represented b a cranio-caudal line of direction) we call this swerve valgu /varus A model like that in Fig 3 werve regularly The swerve f the fo t becomes irregular because the ankle axis changes direction when the O po ition is passed

N rmall the swerve of the ankle joint is c mpensated as require l by p ing m vements in the tal -tarsal j int so that the swerve is lifficult to detect When subtalar arthr de is ha l een performe l however thi comp n ati n mech ni m repe le l and the werve comes to light Thi means that the fo t after perf rma ce

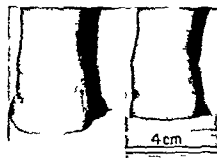


Fig 4
Man aged 48 He had had poliomyelitis as a child and triple arthrodesis as an adult The slight support of 4 cms under the heel made his gait so unsteady that he could not use this height of heel which would have *been desirable be*cause of shortening of the leg

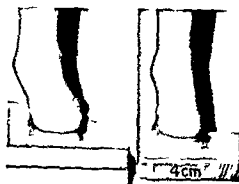


Fig 5
Girl aged 12 poliomyelitis arthrodesis a m Grice *The* shortening of the leg made a 4 cms *heel* desirable so that the arthrodesis may be regarded as being in ideal position despite considerable valgus

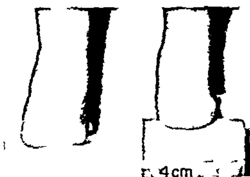


Fig 6
Girl aged 13 poliomyelitis arthrodesis a m Grice



Fig 7
Girl aged 10 bilateral idiopathic pes plano valgus bilateral arthrodesis a m Grice



Fig 8
Man aged 43 cavo-varus triple arthrodesis No appreciable swelling



Fig 9
Woman aged 48 calcaneus fracture triple arthrodesis

Fig 10
Boy ag 1 11 years pes valgus after division of tendon of anterior tibial muscle arthrodesis a m Grice





Fig 11
Girl aged 13 ears Charc t Marie T oth s di e bilateral rthr d

of subtalar arthrodesis places itself in different degrees of varus or valgus according *to the different degrees of height of the shoe's heel*

The extent of the swerve normally varies in breadth according to the individual In a pathological series which feet with subtalar arthrodesis certainly form the variation must be assumed to be larger *than normal This must already be accepted* for the reason that even if the axis passes normally in relation to the malleoli and the talus then a malposition of the heel will produce and abnormal position between the axis and the median plane of the heel with a consequent abnormal swerve of the heel

Figs 4-11 show some examples of how 4 cms lift of the heel influences the valgus/varus position of the heel when subtalar arthrodesis is carried out The individual variation is as can be seen considerable from no swerve (Fig 8) to considerable swerve in the varus direction (Fig 5) None of the examples show swerve in the valgus direction nor can I remember seeing such a swerve at any time in plantar *flexion The swerve seems to be particularly prominent in patients who had polio* as children (Figs 4 5 6)

Now it is the case that the varus position is endured much less easily than the valgus position not least by polio patients

The conclusion is therefore that in the adjustment of a subtalar arthrodesis on the operation table consideration must be given to the degree of plantar flexion which it is desirable for the patient to carry out but which yet excludes a varus position of the foot *In other words consideration must be given to the height of* heel which the patient will require in his footwear after the operation with a slight addition for walking down hills The height of the heel may be determined by cos*metic wishes or by shortening of the extremity*

Allowance for the height of the heel is most simply achieved by undertaking the adjustment of the arthrodesis with the ankle joint in the pointed foot position which the desired heel height requires and not at right angles between leg and sole of foot

With this procedure one does not need to know how large or small is the patient's swerve in the ankle joint *If the swerve is large the foot places itself in a deforming* valgus position when walking barefoot (Fig 5) *but this must be said to be of* minor importance in this connection It is the price the patient must pay to walk comfortably and neatly with shoes on If the swerve is small the fact that the subtalar adjustment *is undertaken with the ankle in the pointed foot position will not* very much affect the position of the foot when walking barefoot (Fig 8) It may be accepted that this procedure is more reliable than with the ankle at right angle the haphazard adjustment of the arthrodesis to some degree of valgus position in order to compensate for the unknown large swerve in the varus direction caused by the shoe heel

Summary

Barnett Napier and Hicks showed that the axis of the ankle joint moves obliquely in relation to the sagittal plane of the foot This means that the foot moves in the *ankle joint like a poorly mounted wheel it swerves from side to side* Normally the swerve is compensated for in the talotarsal joints but when subtalar arthrodesis has been performed there is no compensation The size and variability of the lateral swerve of the heel in a plantar flexion corresponding to a shoe heel of 4 cms is le

monstrated In all the cases demonstrated the heel swerves in the varus direction on such plantar flexion if it does at all swerve

Varus is endured less easily than valgus The conclusion therefore is that in adjusting a subtalar arthrodesis on the operating table consideration must be given to the height of the heel the patient is to use (e g owing to shortening of the extremity) This is done by adjusting the subtalar arthrodesis with the ankle joint in the pointed foot position which the height of the heel requires and not at right angles between leg and sole of foot

DISCUSSION

S v *Rosen* (Malmo Sweden)

A NEW METHOD FOR ASSESSMENT OF THE STATIC AND DYNAMIC WEIGHT BEARING OF THE FOOT (Preliminary report)

b *H Wet enstein* (Stockholm)

A new method has been developed for recording the dynamic and static weight bearing of the foot in a shoe The vertical component of the load is measured in the heel region For this purpo e a stiff pring balance i used in which the deflection is registered by strain gauges

The resolution f the weight bearing load which corresponds to the point of action f the load on the weight bearing surface migrates over this surface in a characteristic way during the weight bearing phase of a step Whether this migrati n is sufficientl significant to allow a demarcatic n f different weight bearing types will be investigated in the continuing work

It is also possible to make similar measurements even under the fore part of the foot s weight bearing surface

The purpo e is to get a technically simple measuring apparatus for objective registration of the fo t s weight bearing n standing and walking in shoes

HAS EPIPHYSEODESIS IN ONE END OF A LONG BONE A GROWTH STIMULATING EFFECT ON THE OTHER END?

by *Henrik V A Heikel* (Bj rnel rg Finland)

Epiphyse de is according to Phemister was erf rmed on the proximal end of the right til ia in 9 92 day ol l rabl it The gr wth was b erved b means of repeated radi logical checks and compared with the left til ia Five ral l its c uld be ob erved during the entire period of gr wth No or only insignificant stimulatic n of growth in the distal end of the right til ia could be observed

DISCUSSION

Göran Bau r (Malm Swe l n) *C Wiberg* (Lun l Sweden)

CARDIOPULMONARY FUNCTION STUDIES IN PATIENTS WITH SCOLIOSIS

(Preliminary report)

by *M Foss Hauge* (Oslo)

At the Sophies Minde Orthopaedic Hospital a systematic study of cardiopulmonary function has been commenced amongst the patients on whom it is intended to operate for scoliosis The tests are being carried out at the University Institute for Respiratory Physiology The studies undertaken are determination of vital capacity maximal breathing capacity CO_2 recovery time after a standardized exercise on a bicycle ergometer and the increase in pulmonary ventilation consequent to this test All the studies were performed with Frikson Scholander s apparatus

32 have so far been examined pre operatively Cardio pulmonary function varies strongly amongst these patients but is generally very poor 14 patients had a function of about ½ the normal 2 had moreover an increase in pulmonary ventilation indicating the probable commencement of heart failure

8 patients out of the 32 were examined post operatively 9 months after osteo fixation of the column (very often 14-15 vertebrae were fixed) In 3 of these cardio pulmonary function was improved in 3 it was unchanged and in 2 of them it was diminished but the difference in function before and after the operation was strikingly small in all patients Amongst those operated on however the tests were undertaken immediately after they had been wearing an immobilising plaster corset for 9 months and their thorax had then scarcely regained its potential elasticity

The research will be continued in the years ahead and it is supposed that a representative series will be reviewed within a relatively short time

DISCUSSION

A Langenskiold (Helsingfors) *S v Rosen* (Malmo Sweden)

ON DETERMINATION OF THE ANGLE OF ANTIVERSION OF THE FEMORAL NECK

by *Folke Tidstrom* (Linkoping Sweden)

DISCUSSION

M Foss Hauge (Oslo)

ON THE TREATMENT OF SEVERE CASES OF EPIPHYSEOLYSIS CAPITIS FEMORIS

by *Istvan Adorjan* (Copenhagen)

A survey is made of wedge osteotomies performed at O H K I dept as a treatment for pronounced slipping of the upper femoral epiphysis in order to contribute towards elucidating the problem of whether this method will be justified in the future in spite of the increasing number of reports of poor results owing to necrosis of the epiphysis or joint cartilage

Out of 18 wedge osteotomies over a 6 year period one third had excellent results

(6) one sixth were poor (3) and half of them were good (5) or fair (4) Total necrosis was not observed in this series The partial necroses healed and were recorded as fairly good Among the poor results was one case in which a pseudarthrosis arose and 2 were due to necrosis of the joint cartilage

It is emphasised that caput necrosis and necrosis of the joint cartilage may also arise in the spontaneous course of the disease

Since no other treatment gives such perfect results as were found in the good group of wedge osteotomies this method ought not to be abandoned summarily according to our experience

DISCUSSION

T Jerre (Vasterås Sweden) *N Lindstrom* (Harnosand Sweden)

BONE BRIDGE FORMATION BETWEEN THE GREATER TROCHANTER AND THE FEMORAL HEAD—A NORMAL VARIATION OF THE PATTERN OF THE OSSIFICATION IN THE UPPER END OF THE FEMUR IN ADOLESCENSE

by *Poul Lütken* (Aalborg Denmark)

The process of ossification of the upper end of the femur shows a peculiar pattern in a fairly large group of mammals In this group the ossification centres of the great trochanter and the caput femoris invade the upper ridge of the collum femoris from either side until they fuse forming a bony bridge joining the great trochanter and the caput femoris together into a common epiphysis while the proximal epiphyseal line towards the diaphysis remains open some months or years to the end of the growth period

This is illustrated by Fig 1 The picture shows the upper end of the femur of a young elephant The bony bridge between the great trochanter and the femoral head is seen clearly

In earlier publications (thesis for the doctorate 1947 and a communication given at the International Anatomical Congress at Oxford 1950) I have described the development of the cartilage skeleton in vertebrates with special reference to the morphogenesis of skeletal epiphyses

My investigations showed that the distribution of certain well-defined surface types in the cartilage skeleton fundamentally identical in mammals and man also as regards the femur

Fig 2 shows a picture of a cardboard reconstruction of the right femur of a 75 mm human foetus The upper end is seen from the side of the great trochanter with the femoral head behind The upper ridge of the collum is seen The border line between the surface types is marked and it is seen that the great trochanter the upper part of the collum and the femoral head are in a common area

From this finding I deduced that also in man the formation of a bony bridge along the upper ridge of the collum was to be expected as a variation of the process of ossification

I was fortunate in finding such a femur in a collection of skeletons found in a medieval grave yard in Jutland used in the thirteenth to the sixteenth centuries and excavated in 1915 and the following years

Fig 1

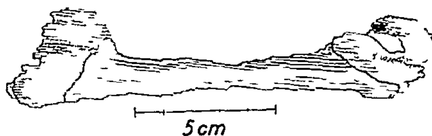


Fig 2

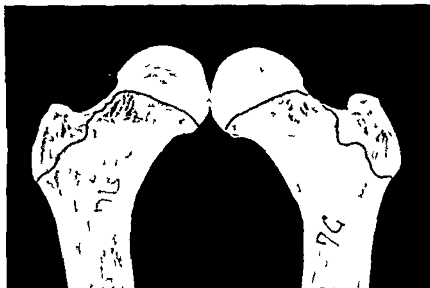


Fig 3

Fig 4



Fig 5

In Fig 3 are seen the upper ends of both femurs of a young human individual On the right femur there is a narrow but distinct bony bridge between the great trochanter and the femoral head while on the left side no such bridge formation is found

After these findings the question of how rare this variation is remained open—and whether it was possible to find it in X rays

In the last 10 years I have actually seen 3 cases of this bony bridge in X rays of children from 11 to 13 years old

Fig 4 is an X ray of a twelve and a half year old boy The bony bridge appears on the left side Two years later (Fig 5) the epiphyseal lines are nearly closed but the bony bridge is now seen on both sides

The next figure number 6 is from a girl eleven and a half years old treated for congenital luxation of both hips and checked regularly since the reposition was done The bony bridge is found on the left side You see slight subluxation and coxa valga on both sides Previous X rays not shown of the same case showed no bony bridge

In Fig 7 the bony bridge is seen on the right side This is from a girl eleven and a half years old treated for congenital luxation of the right side and followed up since the reposition

It is my opinion that the results of my research here presented show that the formation of a bony bridge between the great trochanter and the femoral head

Fig 6

along the upper ridge of the collum is not the result of any pathological process but a normal variation of the process of ossification

These findings seem important in that they contribute to our understanding of the normal development of the upper end of the femur and may influence our interpretation of pathological phenomena in this region

INTERTROCHANTERIC OSTEOTOMY IN ARTHROSIS DEFORMANS COXAE

by *Lars Enander Scharin* (Harnosand Sweden)

Since 1955 in the orthopaedic clinic of Harnosand intertrochanteric osteotomy has been adapted to arthrosis deformans coxae We began first with the method described by McMurray i e osteotomy alone and plaster fixation for 3 months 7 such operations were performed We made the same observations as many others namely that after this type of osteotomy the mobility of the hip joint was considerably diminished and in addition the possibility of movement in the hip joint was hazarded Treatment was very lengthy The result was best compared with a less successful arthrodesis Starting from this point therefore we changed to inner fixation of the osteotomy First of all the plate introduced by London surgeon Kessel was employed and this was inserted into the trochanter region and then attached by screws to the femoral shaft (Fig 1) 20 cases were operated on 10 men and 10 women The average age at operation was 50 70 years 11 patients had arthrosis in one hip joint and 9 in both Out of these 9 with bilateral hip joint arthrosis 3 had trouble in one hip only and 6 in both All were followed up and the observation period was 1 2 3 years The results can be seen in Table 1

TABLE 1

Cases operated on according to Kessel

Subj		*Complications*	
Free of pain	9	*Pseudarthrosi (4 reop)*	8
Improved	7	Thrombosis	[illegible]
Unchanged	4		
	20		

Objectively it was found that mobility which primarily was between 60 and 90 degrees on the whole remained unchanged and was almost normal As Table 1 shows 8 pseudarthroses were present from the osteotomy None of these patients had fixation in plaster but were kept in bed for 6 weeks and afterwards allowed to put weight on the operated leg After consideration of the high frequency of pseudarhtrosis another method of fixation was adopted i e. that described by Mcgee and Nissen (Fig 2)

33 patients were operated on 2 bilaterally At the time of operation the patients were aged 50 70 years The etiology of the arthrosis change was in 3 cases subluxation 3 trauma 1 epiphysiolysis and 1 chondromatosis 2? were unilateral cases 11 bilateral Previous operations were collum nailing in 1 case curettage 1 ... trochanteric osteotomy 1 capsulectomy 1 31 were followed up The observation period was 1 3 years The results are shown in Table 2

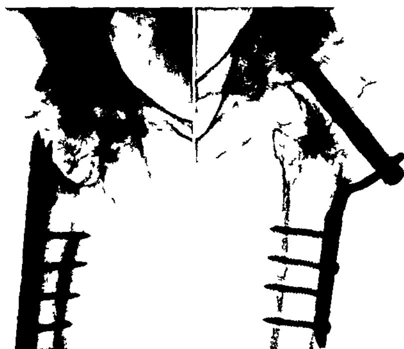


Fig 1 *Fig*

TAPLE ?
Cases operatel on according to McKee Nissen

Subj		*Complications*	
Free of pain	?1	Pseudarthrosi	5
Improved	3	Thrombo is	6
Unchanged	7	Subtrochanteric fracture	1
	—	Post op pneum nia	1
	31		

In this material above could determine that the mobilit f the hip j int had l v and large been maintained but yet wa less in 10 ca e in one of which the mobility was onl 10 degree This ca e was then operated on f r arthr desi All pseudarthro es were re operated on and healed

Conclusi ns

1 Intertrochanteric steot my with inner fixation gi es freed m fr m pain relati ely unchanged m bility and stab lity t a high degree in c xarthrosis How lasting the effect is cannot be judged from this material Other publi hed studies indicate that one can be quite optimistic on this point

2 By means of inner fixation the patient avoids plaster and bed rest need not extend beyond 6 weeks possibly this period can be reduced

3 One may speak of a conservative effect on the hip joint in that the arthrosis process is arrested Certain authors argue that regression occurs One cannot go so far as this judging only from the present material

4 In selection of patients those should be considered in whom the process has not advanced too far and where large destruction of bone substance has not occurred Instead one should choose cases with early arthrosis and well preserved mobility

FOURTEEN YEARS EXPERIENCE WITH SMITH PETERSEN'S ARTHROPLASTY

by *C Semb A Jakobsen* and *H K Dahl* (Oslo)

In Ullevål hospital dept III vitallium cup arthroplasty have formed the sole method since 1946 of treatment of hip joint arthroses Adjusting the method to a certain extent we have also used it in residual conditions following arthritis aseptic necrosis and pseudarthrosis and lastly also in unsuccessful alloplastics Up to May 1st 1960 we have operated on a total of 650 hips according to the Smith Petersen method 437 in Ullevål hospital and 213 amongst professor Semb's private patients The first 301 hips operated on were studied earlier and reviewed in A Jakobsen's publication Vitallium mould arthroplasty

We have all the time kept to firm indications for operation —the patients must be in considerable distress and we have attached special importance to the symptom complex pain reduced mobility and instability As we gradually accumulated experience certain changes were made in operative technique The following details are to be emphasised

The capsule must be radically extirpated The resection of the caput ought not to be too radical If it is too radical a short neck is the result giving instability Devitalised bone which must be removed is replaced by the transplantation of cancellous bone Thus one avoids reducing the level of the caput If the caput is necrotic and must be sacrificed the trochanter must be transplanted to obtain a longer neck and better stability We have abandoned resection of the whole or part of the trochanter major

In dislocations and dysplasia the acetabulum should be placed at the correct height where the acetabulum is shallow it must be chiselled out radically sufficient of the rear and lower edge must be removed and a smooth and oblique finish below the acetabulum should be aimed at If one does not take sufficient from the rear lower edge extension is not achieved Use as large a cup as possible this gives better mobility the cup must rotate freely in relation to the caput and in relation to the acetabulum In individual cases some form of shelf operation (acetabular roof plastic) will be necessary from the standpoint of stability Raw bone surface on the collum and acetabular edge are covered with bee wax to prevent new bone formation There should be postoperative prophylactic anticoagulation treatment from the 4th to the 5th day Physiotherapy will be given postoperatively along the lines drawn up by Professor Smith Petersen Do not allow weight bearing on the operated extremity for six months after the operation preferably 1 year in case of aseptic necrosis

The first 301 hips operated on were re examined in 1954 and since January 1st 1960 the same series has again been examined The minimum observation period for these patients is now 9 years and the longest period of observation 14 years with an average observation period of 11.4 years

During the observati n period apart from the one postoperative death in all 33 patients passed awav but 3 of these were included in the last examination when we were able to asses their conditi n before the died Thus 2?0 patients were available for follow up with a total of ?68 operated hips Up to the present per sonally or by questionnaire and by X ra of a new date 182 patients with 221 operated hips have been followed up

The clinical results are assessed according to the same principle as was used in Arnt Jakobsen s publication

The results of the series appear in the table below

Our conclusi n from the follow up is that the patients who had a good result primarily maintain this and our observation period is now so long that we believe we can say that the results are lasting We therefore consider that there is every justification in continuing to use the same method since in our hands it has pro duced such good results even in the long view

TABLF

Operated	301 hips (?50 patients)	
Followed up 1960	2?1 hips (18? patients)	
Died postoperatively	1 patient (1)	
Died during observati n time	33 patients (36)	
Mean ob ervation time	11 4 ears	
Clinical results	1954	1960
Excellent	54	52
Co d	89	86
Fair	52	57
Poor	?6	26

DISCUSSION

C Hirsch (Upsala Sweden) C Semb (Oslo)

C W berg (Lund Sweden)

There i every reason t c ngratulate profes or Semb on the excellent results which with hi great exp rience he has achieved in cup plastics It deserves t be pointed ut however that in the treatment of arthr is def rman of the hip j int other operative intervention ma also be justified and that there are grourds f r s rving the op r tive type s metimes Al ve all I would once again emphasise that arthrodesi for variou ounger patients wh make great demands n their tanding and walking capacity may be preferred t an arthr pla t

PATHOLOGICAL FRACTURE OF THE FEMORAL NECK IN CHILDREN
A COMPLICATION OF HAEMATOGENOUS OSTEOMYELITIS

By A Dxler and I I sorn (Seraje Jug lavia)

The di eas of acute haemat genous o teomyelitis is ch racteri ed in m st Eu r pean countrie by a diminishing incidence and at the me time l les grave manifestati n of the disea e

This is also happening i Jugoslavia

It may well be attributed to both the general improvement in living standards and to the special medicinal advances based on the manufacture of a steadily increasing number of antibiotics

But the change described in the incidence of the disease and its clinical features is certainly also a result of the increasing interest of recent decades in the special pathology of childhood Nonetheless acute osteomyelitis in children is still a grave reality home in Jugoslavia with the following etiologic and pathogenetic background insufficient food and lack of personal hygiene is relatively common even in our days especially in the country districts

For these reasons skin abscesses and other pyogenous inflammations are general here

We regard such localised inflammations—combined with repeated slight trauma—as the most important causes

Infected scratches in children—who like to walk barelegged when it is warm—represent the typical focus of haematogenous osteomyelitis

In spite of the favourable course and the improved prognosis one must continue to expect to meet a number of complications in acute osteomyelitis

To these belongs the pathological fracture of the neck of the femur it is true that it is rare but nevertheless it is important because it has such serious consequences

During the last 5 year period 1955 to 1960 62 patients in the age group under 14 years were treated for acute haematogenous osteomyelitis of the femur at Sarajevo in the surgical clinic

According to the localisation of the inflammation one can divide the patients into the following groups—illustrated in Table 1

TABLE 1

Proximal part of femur	36
Middle part of femur	17
Distal part of femur	9
All	62

36 children with osteomyelitis in the upper third of femur

17 children with osteomyelitis in the middle third of femur

9 children with osteomyelitis in the lower third of femur

The incidence of disease in the two sexes and in the different age groups appear in Table 2

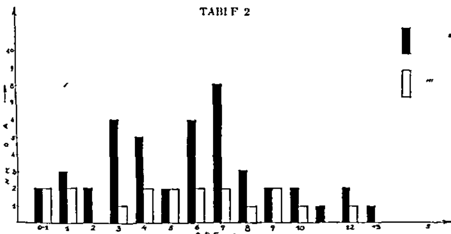
The figures show that the majority of the cases appear in boys in the age group 3 7 years which is not surprising because they are most exposed to trauma and incur most frequently small infected wound

Of the 36 patients who had osteomyelitis in the upper end of the femur 14 i e g 1 third of the cases were found to have purulent joint affection

In 8 cases the inflammation involved after a short time destruction of the neck of the femur culminating in fracture i e in 22½ of the patients in whom osteomyelitis was found localised to the proximal third of the femur

The majority of the 8 patients i e 5 represents advanced and partially neglected cases which had incurred their fractures before admission into hospital

TABLE 2



In the three other cases the destructive process had not progressed so far and here more moderate degrees of dislocation were present

Treatment was in all cases conservative in the acute stage this included large dosages of antibiotics immobilising plaster or zinc paste traction and suitable hygienic dietetic regime to improve the general condition combined with the neces sary relieving incisions

The treatm nt results pr ved to be g od in the three cases in which the therapy c uld be commenced at an early stage

Then one could prevent the malformation and restrict the inflammatory changes bef re any irreparable b ne de tructi n had occurred

Thus fracture consoli lati n was achieved in a g od p siti n a will now be illustrated by X ra pictures and phot graphs of one of the e three patients Photo 1 and X ray Series 1

In the other gr up of p ath logical fracture c mpri ing the 5 advanced cases there are 3 patient wh stand ut becau e their re ult in pite of e erything r sati fact r fr m the functi nal p int f view But a certain def rmity could n t be a oided in these case

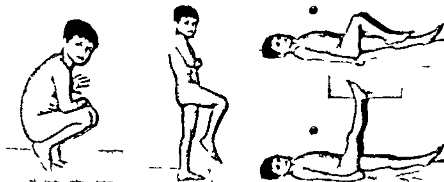


Photo 1

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The majority of these 8 patients i.e. 5 represent advanced and partially neglected cases which had incurred their fractures before admission into hospital

litis had not been diagnosed and not been treated during the whole of that period In spite of immobilising traction treatment and uitable antibi tic therapy the end result was complete collum resorption and destructi n of the caput femoris —as we now see from these X ray pictures X ra series 4

Table 3 comprises the results of treatment in the 8 cases of pathological fracture which makes up our series

Discussion

Our series comprises a relatively large number of cases of acute osteomyelitis in the upper end of femur and sh uld therefore present a repre entative picture of the collum neck fracture s incidence in this c nditi n

One may then say according to ur investigations that where haematogenous osteomyelitis in children has first attacked the pr ximal third of the femur there is ever reason to be on guard against a development leading to pathological fracture of the collum neck

The eries shows indeed that this complicati n occurs frequently when one con siders its incidence in relation to patient group which forms the basis of assessment

More ver it is obvious that the path logical fracture of the neck of the femur arises with a higher incidence and in its gravest form in children who have recei ed insufficient treatment

On the other hand it appears that this complicati n can be avoided as a rule by early and suitable treatment—and where fracture cannot be avoided that in any case functionally satisfactory end results can be secured

In other words the task of our treatment is primarily proph lactic in nature by means of earl diagnosis of the acute o teomyelitis in children Furthermore im mediate ho pitalisation is required bearing in mind suitable antibiotic therapy com bined with energetic efforts to improve the general conditi n In this connection we would menti n that we believe we deri e great benefit from the bacteriological resistance condition as a basis for ch osing the antibiotics

In addition we have placed much weight on strengthening the child s abilit to resi t the disease through blood transfusions al ngside the normal hygienic-dietetic rules

If in spite of the treatment regime a path logical fracture of the collum neck occurs then it has turned out that with trict supervision during traction treatment we can still prevent the gravest consequences of the ab ve complication by avoiding c mplete destruction of the collum and caput

With neglected ca es h we er one cann t guard against the l s of the joint n uri hing part of the upper femur end which in olves lasting invalidisati n of the e small patients Infirmity can onl be partly eff ct by means of secondary surgical interventions like arthr le is r arthr pla ty cr c rre tive oste tomies

This operative treatment i n t undertaken naturall until all acut ign of inflammati n have di appeare l—an l the patient is fully recove ed a far as the general health is c ncerne l

Then we u u ll send all children wh are t und rg th ab o e urgi al treatment t the c nvale cence h me n the A lr atic t which i known f r its mild and sunny climate

In the acute tage we mu t give way t urgical treatm nt in the f rm of in i i r an l drainage wh re it eems nec ary

We have not found any grounds for adopting such relieving osteotomy as normal treatment — on the contrary it is only used in exceptional cases.

In addition it is natural to discuss undertaking puncture and evacuation of the hip joint where pyarthrosis is present — possibly combined with intra-articular antibiotics.

Finally there is the question whether *traction treatment should not be carried* out as the normal method for every osteomyelitis which affects the joint even in early cases both to relieve subjective trouble and to prevent *further* traumatisation of the *necrosis* threatened cartilage.

DISCUSSION

G. Wiberg (Lund, Sweden), *C. Semb* (Oslo) and *H. Holmdahl* (Boden, Sweden).

ON THE UPTAKE OF RADIOACTIVE CALCIUM AND STRONTIUM IN THE SKELETON OF RATS

by *Hans Bohr* (Copenhagen)

THE BONEMETHABOLISM IN TIBIAL FRACTURES IN MEN

by *Bo Wendeberg* (Malmö, Sweden)

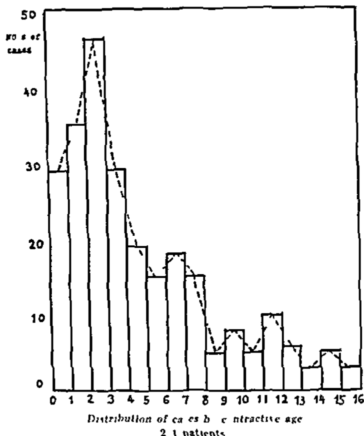
ON INEQUALITY IN LENGTH BETWEEN LOWER LIMBS AFTER POLIOMYELITIS WITH UNILATERAL INVOLVEMENT AQUIRED DURING THE GROWTH PERIOD

by *Rolf Lindholm* (Helsingfors)

Inequality in length between the lower extremities is caused by various disease conditions (congenital malformation, infection, tumours and trauma). By retardation of the growth period poliomyelitis is the commonest cause of inequality in length of lower limbs. The specific *origin of* the growth disturbance in poliomyelitis is still unknown. The problem of therapy is likewise an incomplete chapter in orthopaedics. Skeletal operations such as epiphysiodesis on the longer extremity and which aim at correction of the inequality are best served by an accurate prognosis of the final figures of the inequality so that the operation may be calibrated correctly in all respects. *Retardation* values following epiphyseodesis are obtained by tables drawn up by Green & Anderson amongst others. Anticipation of the size of the final inequality has always been an uncertain *matter* after poliomyelitis. A general view, also held by Steindler, has been that the difference in *length* would depend both on age at the onset of disease and on the extent of the paresis. Surprisingly enough however Stinchfield, Reidy & Barr 1949 could find no correlation between age at initial disease (0-10 years) and the degree of inequality. They based their opinion on a clinical series comprising 300 patients, 64 with bilateral involvement.

This *investigation* was carried out in order to *throw* light on the size of the inequality in length and on the possibilities for prognostic evaluation. Only unilateral cases were chosen as the object of study so that as far as possible the influence of the other limb was eliminated in cases of bilateral involvement. The literature confirms that inequality in length in bilateral paresis remains less than in unilateral cases.

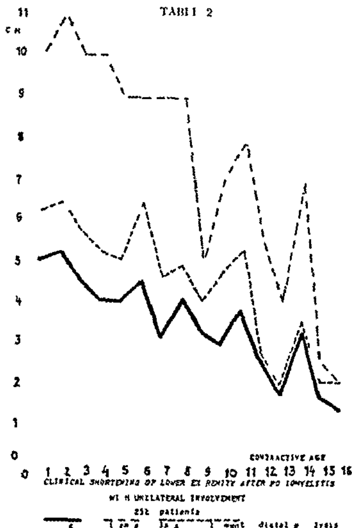
TABLE 1



Distribution of ca es b c ntractive age
2 1 patients

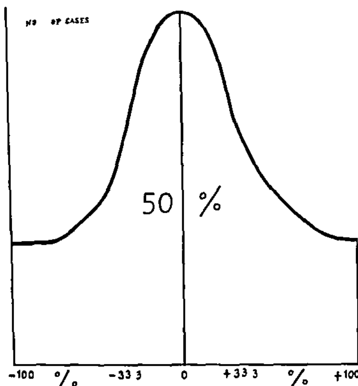
The prol lems which were a sumed to be capable of elucidati n at first hand were 1 The al solute extent of the true incongruence 2 Its relation to the contractive age 3 Its relati n to the spread of the pare es and the degree of severity

The *material* was ma le up of 251 cases of poli myeliti in one lower liml acquired during the growth peri d from 0 t 16 years The distribution of the cases according to c ntractive age appears in Tal le 1 The clinical shortening wa ol erved in the affected limb after ce ati n f skeletal growth By clinical sh rtening i meant the difference between the spine malle lus measurements The mea urement in que ti n d n t give an exact value f r the length of limb l ut indicate a well a the listance fr m the me lial malle lu tip to the cranial end f the caput fem ri al the di tance from the latter point to the spine iliaca ventralis Onl with an ther wise intact skeleton were inclu led Theref re this exclud d cases f t t my c n genital d f rmity traumatisati n etc In this way s urce f err r wer a it l u h a the influence n the length of an other p ible di turl anc f epiph eal gr wth



As regards degree of paresis the cases were grouped according to the following plan 1 Cases with distal paresis — cases with only wrist and foot muscles affected in varying degree while knee and hip muscles remain intact 2 Cases with extensive pareses — cases with all "main" muscle function affected to a marked degree By main functions is meant flexion extension abduction and adduction in the hip flexion and extension in the knee and also dorsal plantar flexion eversion and inversion in the foot By involvement to a "marked" degree is meant that condition in which all "main" muscle function are reduced to a value not 3 (i e that the muscle strength is at its peak equivalent to the force of gravity in the direction of the movement but not beyond) Grouped in this way two distinctly separate types of cases were constituted with the greatest possible difference This was in order to demonstrate very clearly the possible relationship between the degree of paresis and the inequality in length

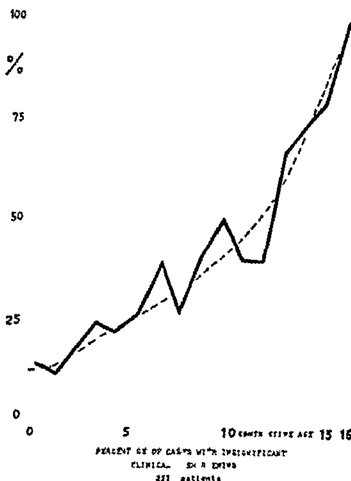
TABLE 3



FREQUENCY DISTRIBUTION IN RELATION TO
HIGHEST AND LOWEST VALUE OF SHORTENING
IN EACH GROUP OF CONTRACTIVE AGE
251

The arithmetical mean in cms of the inequality in length in all cases of the various age groups was calculated and also separately that for the distal pareses and the extensive pareses Furthermore the extreme values of shortening within each category were noted In practice the low extreme values are represented by the value nought in each group showing that independently of the degree of pareses and the contractive age some case was present with non existent inequality in length The mean for the greatest and least amount of shortening proved to coincide quite well with the mean for all cases in the various age categories The difference in the resultant length between the distal and the extensive pareses appears plainly in the diagram in Table ? The falling curves show the tendency toward diminishing inequality as the age rises during the period at which poliomyelitis is incurred The first group demonstrates an exception when patients contracting the disease between 0 and 1 year of age exhibit a somewhat smaller average of inequality than the following group taken ill between 1 and ? year of age The number of cases probably lends the result a certain significance

TABLE 4



The normal curve in Table 3 shows quite a good concentration around the middl alue but with a considerable number of cases near the maximal and minimal values of inequality The curve is constructed on the basis of percentage departur from the average of maximal and minimal hortening per age group About half f the cases are found within—33.3 % divergence from the average figure which mean for example for the 35 cases contracting disease between 1 and 2 years f age with an inequality arying between 0 and 11 cms shortening that about half had an inequality between 4 and 7 cms Thi relation hip indicates that a marked unc r tainty regarding the prognosis is undoubtedly pre ent if no other criteri n except what is now recommended is employed

The incidence of cases with negligible inequality (bel w ? cms) i graphic ll represented in Table 4 a a percentage relation hip of the whole number irrespecti of the degree of paresis The general tendency is plain an increasing number of ca es with negligible shortening as age increases on contracti n of the di ea e The risk of an inequality appearing with clinical importance seems for patients acquir

ing unilateral poliomyelitis between 0 and 2 years of age to be thus about 90 % to fall later as age increases to about 0 at 15 or 16 years of age. It should be noted *that the diagrams refer without distinction to men and women so that prognosis* conclusions in individual cases may only be drawn with reservations.

In conclusion it may be stated: 1. The size of the final inequality in length in the lower limbs following unilateral poliomyelitis during the years of growth is in indirect proportion to the age of the individual on contraction of the disease (possibly with the exception of group 0–1 years which shows slightly less inequality than the above statement indicates). 2. Distal involvement of the lower limb with intact knee and hip muscles generally produces less inequality on average than widespread involvement of all main muscle functions (test value not above 3). 3. Forming prognoses on the basis of the diagrams included in this study should be made with reservation owing to a) the relatively large spread toward the extreme values and b) the absence of differentiation between the sexes. 4. The probability that the inequality will remain within negligible limits (under 2 cms.) is however great in cases of solely distal involvement (wrist and foot muscles) from the age of 6 and 7 upwards at the time of contraction of the disease. Much risk of considerable inequality is present with widespread pareses as late as 9–10 years of age on contraction of the disease. Inequality of clinical significance occurs still in isolated cases after contraction in the 12–13 age group. 5. The highest average value of inequality is found in the group taken ill at 1 to 2 years of age and consists of 6.3 cms. with widespread pareses and 3.7 cms. with distal involvement. The highest inequality values in individual cases of varying age when taken ill fluctuate from 11 to 2 cms. with a tendency to fall as the age group rises. A small number of cases with non-existent difference in length even with extensive pareses are to be seen in all groups at various ages of contracting the disease.

METAL PLATE WITHOUT SCREWS FOR FIXATION OF SHAFT FRACTURES OF THE FOREARM

By *Erik Moberg* (Gothenburg, Sweden)

It is not generally known that almost a third of the diaphysis fractures of the forearm in the radius or ulna end in pseudarthrosis. Large groups of statistics—even from the most recent time—reveal however how difficult these fractures are to heal.

Through previous studies together with my collaborators I was able to show that bony union can be obtained in almost every case if rotatory movements at the fracture site can be prevented.

Earlier in our series this was effected by inserting into a slit made by a bone saw a self-locking strong cortical bone graft. The technique required for this however *is not too easy* and especially when fractures of the two diaphyses simultaneously are present a large quantity of bone material must be used with the risks this brings to the donor site.

In a series now amounting to 19 such shaft fractures I have replaced the above self-locking bone graft with a self-locking steel plate inserted in the same way as the bone transplant. Sometimes the metal plate may require to be fixed by a transverse piece of Kirschner wire. To make this locking possible the plate has a [illegible] shown in the figure.

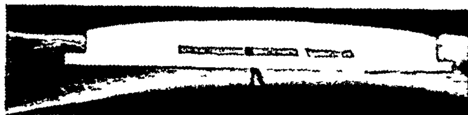


Fig 1
Metal plate inserted in position locked by a piece of transverse Kirschner wire through the slit Model fracture

It has turned out that bony union was obtained in 18 out of 19 cases in this way while in one case the plate was too short to give sufficient fixation It had to be replaced in this case on re-operation by a cortical tibial graft Amongst those treated in the way mentioned also cases of pseudarthrosis in diaphysis fractures are included

The advantages of the method by comparison with other ways of metallic fixation of these fractures are

1 The elbow joint and wrist joint are not included in the area of intervention
2 No circular dissection with injury to the nutrition of the bone ends is necessary only unilateral dissection
3 The drawbacks always connected with screws are avoided yet very stable fixation is achieved hindering in particular deleterious rotation
4 The operation becomes easier although not easy since exact work is required

Naturally the surgery is completed by a rotation preventing plaster which must have a firm grip both around the metacarpal region of the hand and the distal part of the upper arm

DISCUSSION

M Foss Hauge (Oslo) *C Hirsch* (Upsala Sweden) *I Hult* (Umeå Sweden) *C Weberg* (Lund Sweden)

BONE TRANSPLANTATION WITH THIN TIBIA CORTICALIS AND SCREW FIXATION

by *Erin Madsen* (Sorø Denmark)

I should like to present the results of a series of bone transplantations on the long bones employing a technique which was determined some years ago We decided to use a thin tibia graft secured by means of vitallium screws The tibia graft is thin both because a lesser lesion is thus made on the tibia the marrow cavity not being opened and because we think that the thin graft would heal more quickly Using screw fixation one achieves a fixation of the fracture After applying the tibia graft we place bone chips around the site of the lesion taking the chips from the newly formed bone tissue around the lesion The tibia graft is about 4 mm thick about 16 mms wide and quite long e g in a tibia fracture about 14 cm long The graft is sawed away from the medial aspect of the tibia and from its anterior

border in such a way that the marrow cavity is not opened The graft is put in a vice Its corners are smoothed off so that it does not project unnecessarily and holes 4 mms in diameter are drilled i e large enough to prevent the vitallium screws biting into the graft A 3 1 mm drill is used when drilling into the bone The graft is attached solidly to the bone and we believe this is important for perfect contact and good healing If the fracture position is good *no* resection of the fracture site is made but a flat surface is made at the fracture site so that the graft can fit closely to the bone throughout its length If the fracture position is poor the fracture is loosened a little of the ends is resected the latter are adjusted and after Beck s drilling reduction is performed and the fracture is fixed with the aid of the tibia graft on its shaped bed Only as little of the bones as is necessary is taken for this purpose Generally we can obtain sufficient chips from the newly formed bone tissue and we have taken bone chips from the iliac crest only occasionally With few exceptions unpadded plaster splints were used until clinical healing occurred *Clinical healing* is the term used from the time that *the patient begins to support himself on the leg or to use the arm and can continue to do so without feeling pain or tenderness at the fracture site*

In this way we *operated on 40 patients with 49 fractures* The material was examined by Jorgen Stougaard who published the results of the major part in Nordisk Medicin The follow up examination took place from 11 months up to 8 years after the operation There was no fatality in the series In one case a tibia fracture a slight infection arose in the wound 3 weeks after the operation The infection disappeared and had no effect on the healing time which was 3 months There were no other complications

Owing to lack of time I shall confine myself today to the discussion of the actual results of healing since the *function* of the different extremities in the follow up (those Stougaard has reported) was good in the great majority of patients and essentially depended on whether a lasting reduction in function had already arisen *before* the osteoplastic operation Most of the cases were admitted to Soro Hospital after primary treatment elsewhere The cases which were primarily treated for the fracture at Soro Hospital were given transplantation treatment quite early since we aimed at carrying out bone transplantation at a relatively early stage i e as soon as we obtained the diagnosis of delayed healing We operated early to avoid diminishing the function of the extremity by having too long a period of plaster splinting In a number of cases in particular with the antebrachium we employed bone transplantation as the primary treatment to ensure union of these fractures which often heal only with difficulty

Survey

Operated 40 pts with 49 fracture
Healed 39 pts with 48 fractures
Period of healing (average) 2 2/3 months
No healing in 11 months 1 ulna

As stated above 40 pts with 49 fractures were operated on of whom 39 pts with 48 fractures healed with an average healing period of 2 2/3 months The one who did not heal had an antebrachium fracture where the ulna was not healed 11 months after the operation

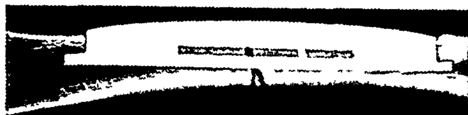


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Diverse bones 7 cases

Humerus 2 cases healing peri 1 ? ½ and 5 mths aged 58 and 73 years 4 and ? mths before operation
Femur ? cases healed after 3 and 3 mths aged 23 and 68 3 and 5 mths before operation
Clavicula 1 case healing period ?½ mths age 38 yrs 10 mths before operation
Metacarp III IV V 1 case healing period 1 mths age 21 yrs 3 mths before operation
Metacarp II III IV 1 case healing period ? mths age ?1 yrs ?1 mths before operation
Resection in all these cases

For the other bones we have some scattered cases 2 on the humerus united in 2½ 5 mths ? on the femur both united in 3 mths 1 clavicula united in ? mths and also 2 hands each with 3 metacarpal fractur which all united in about ? months Here as before it will be seen that the long period before the operation did not play any deci ive part in the healing time after operation In one case with metacarpal fractures 21 months passed before operation On the femur we see again that the young and the old heal in the same time In the femur we employed simultaneously with the bone graft a very solid vitallium plate in a plane at right angle to the plane of the graft and did n t u e plaster bandage after the operation

Finally I should like to point out that when different methods of transplantation are compared I do not believe that it i sufficient to discu e rtically ver u s n g sa r ver us b ne chip etc but one must take into consideration that the dimensions of the grafts accurate adjustment method of fixation and other technical details play an equally deci ive part in the healing results as the kind of material

FIXATION OF THE TIBIO FIBULAR SYNDESMOSIS BY MEANS OF CERCLAGE THROUGH DRILLED HOLES

by *Lars Martenson* (Gothenburg Sweden)

The stud is intended to be published in Acta Orthopaedica Here i merely a h rt ummary

Ever ne knows f the ... difficulties inv lved in maintaining a ati factor reducti n p siti n which has been obtained by cl ed reducti n in ankle joint fractur s Therefore interest in acti e per tive treatment f fracture in the ankle j int region is c n tantly increasing

If ne p e e thi acti e app ach h wev r it i nece ar c n t ntly t take int c n ideration two elem nt f t

1 T (n ert a littl n i f m th p int f view f t u re t ti n a ha mle te nthe i m t ri l p ill

? T judge th qu l t an l pre an f th kin os ring p m rll with c n ideration f th nut iti nal injurie pr um t t r e n tr uma

At the Surg l Ext emit Clini in G th nb rg fr m whi h t i t l ha rr ee l t w ha l t l a m k ll ti e app a h t th treatm nt f th in juries

After the operative method it elf is demonstrated a surgical material of in all 60 cases is reported covering the period from the 15th October 1959 to 30th April 1960. Statistical information on the following questions is given in table form

a) age at accident
b) age distribution during the months most prone to accidents
c) cause of accident
d) incidence of triple fractures
e) importance of the skin problem

Included also is inforamtion on average period of care period before weight bearing on foot late problems of primary treatment when the patient has not yet been discharged

DISCUSSION

I Hagelstam (Helsingfors) *Hans Dahl* (Oslo)

C Wiberg (Lund Sweden)

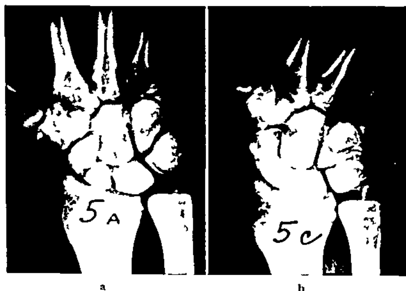
As is well known syndesmosis injuries combined with fracture lead in a large number of cases to late arthrosis deformans changes within the talocrural joint and even if these changes are many times of slight nature such a foot gives symptoms many times Even with the very simple fractures to the lateral malleolus alone the consequence may be lasting with limitation of e g the possibilities of sport Since we know from experience that the risk of deformans changes becomes less if an intra articular fracture is accurately reduced it seems a justified procedure in these fractures to undertake an operative correction and perhaps to a larger extent than has hitherto been the case During the last 2 years we have taken the step at the orthopaedic clinic in Lund of operating also on these fibula fractures and so one finds that the distal fibula fragment lies about 5 outward rotated and a few millimeters upward-displaced which is sufficient to create incongruency between the fibula and the lateral talus articular surface It is of course much to early to express an opinion on the effect since the deformans change discussed earlier do not occur until after 10 15 years and research in the future must therefore reveal if our argument is correct

PSEUDARTHROSIS OF THE CARPAL NAVICULAR BONE OF THE HAND TREATED BY INFORATIO ACCORDING TO BECK

by *Jorgen Frost* and *Henrik Hamburger* (Copenhagen)

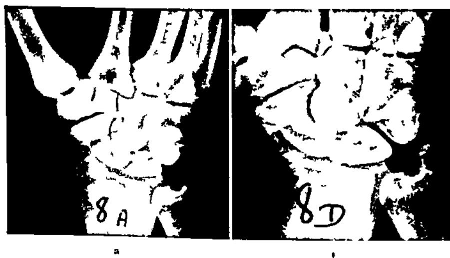
In the surgical department of Copenhagen s Military Hospital 86 patients were treated during a 5 year period from 1955 1960 for fracture of the navicular bone of the hand 51 of these 86 patients were designated as fresh i e recognised less than 4 weeks after trauma and 35 were designated as inveterate i e not recognised until 4 weeks after trauma 19 of these within the first half year 8 in the second six months and 8 between 1 4 year following trauma

Out of the 51 fresh cases 48 were successful using plaster bandage alone while 3 pseudoarthrosis arose



a b

Fig 1
Patient no 5 before and after Beck drilling



a I

Fig 2
Patient n 8 before and after Beck drilling

4 of the 35 inveterate ca es were sent h me n milit ry gr nd n l the ef e were not fully treated 21 patients were treated exclu vely with pla te nd g and on f ll w up examinati n it pr ved that 15 ha l uni n n l 6 n n uni n Of the remaining 10 ne patient on wh m we shall rep rt later was tr ated by X ray The

GROUP

Beck drilling in 3 patients whose fracture was recognised immediately (i.e. within

Pt. no.	No. of mths in plaster before op.	X-ray films at op.	No. mths in plaster after op.	Follow-up no. mths after end of treatment	Subj. cll.
3	5	sclerosis + cyst	3	18	slight pain with hard work
4	8	sclerosis + cyst	2	18	no complaint
7	4 mths and afterwards 4 mths — treatmt	sclerosis	4	3	moderate trouble with hard work

GROUP

Beck drilling in 9 patients whose fracture was inveterate (i.e. more than

No. of Pts.	Previous visited doctor	First X-ray	Fracture recognised no. of mths after trauma	X-ray films at confirmation of diagnosis	No. of mths plaster before op.	No. of mths after op.
1	at once (+ treated before for 2 mths)	at once	6	sclerosis + cyst	8	[illegible]
[illegible]	at once	nothing abnormal	20	sclerosis + cyst	3	[illegible]
5	at once	X-ray	8	sclerosis + cyst	0	4
6	no		10	cyst + fracture	[illegible]	
8	no		24	sclerosis + cyst	0	
9	no		48	cyst + fracture	0	3
15	no		24	sclerosis	[illegible]	3
10	no		12	cyst	3	about
11	at once [illegible] trauma unknown	[illegible] arthrosis	[illegible]	cyst fracture	2	about [illegible]

weeks) and in whom no success was achieved with the routine plaster bandage

T... dern ... these S...ff box	Mobility	X ray finding	Work	Total result
0	4/5	Union	+	Fine
0	4/5	Union	+	Fine
(+)	2/3	Partial effacement of fracture line	+	Improved

...eks (II) when they came for treatment at Copenhagen's Military Hospital

...llow up ... of ... th ... after end of treatment	Subjectively	Time in the S...uff box	Mobility	X ray findings	Work	Total result
	no trouble	0	4/5	Union	+	Fine
0	no trouble	0	4	Union	+	Fine
13	no trouble	0	4/5	Union	+	Fine
[illegible]	no trouble	(+)	2/3	Union	+	Fine
1	no trouble	(+)	2/3	Union		Fine
3	no trouble	0	2/3	Partial effacement of fracture line	+	Improved
3	no trouble	(+)	4	Union	Will [illegible] gin [illegible]	Fine
24	Is at mental hospital treatment was interrupted			[illegible]	+	Unchanged
	Treatment interrupted owing [illegible]			[illegible]		Unchanged

remaining 9 and the 3 non united patients from the group of fresh ca es were surgi calls treated and the present studs therefcre cencerns the e 12 patients cperale l on and the patient treated l v X ras

Croup 3 X ray treatment of pseudoarthrc sis of the n u icular bone

An ensign aged 25 who first sc ught treatment 1? months after trauma On X ray examination pseudarthrosis was f und with irregularly sclerc sed fracture lines He was treated with a total of 375 r and has ncw been examined 4 years after ccn clusion of treatment Subjectivels minimal pain is reported when w rking hard an l objectively a mcbility amcunting to s that cf the healthy hand was found

Hand grip 75 against 1?0

On X ra examination a nearthrosis can n w bc een with sm cther g l locking *articular surfaces and no sign of secondary arthrosis— thu recalling the result fcl* lowing a Bentzon operation

As the tables sh w certain csseous union arcse in 8 of the 1? patients M bility in the wrist joint was alm st normal e pecially in the case cf thc e l erve l cver a long period

In 2 patients the fracture unicn i designated as partial but b th these patients are working and it seems t them that the hand imj roved after operal n They were both only cbserved for 3 months after the c nclusi n f treatment s further im provement is till possible

In 2 patients no union occurred In re pect of lcth f the e patients it may le said that the length of after treatment i uncertain an l was nly carrie l cut l y us f r about 2 months They were sent h me and the department ha l n cj rtunity therefore t direct the after treatment itself

Finally as already stated cne patient was X ray treated It was lef re Beck drilling ccmmenced and the th ught behind the X ray treatment aimed at achieving s mething along the lines cf what is achieved with Bentz n s prcce lure The sm th edged nearthrosis and the functionally g d result indicate succe

The treatment of fractures of the navicular b ne f the hand rec gnise l at an early tage is a rewarding ta k as cur tctal series will sh w

48 ut of 51 fresh fractures healed with pla ter landage al ne an l 30 patient healed after cnly 2 mcnths in plaster 17 ha l pla ter lan lage f r 3 f m nths an l *nly 1 remained in plaster for m re than 6 m nths*

In applying the plaster it is important n t cnly t l ck the m vements cf the thuml and wrist lut als the rctat ry m vements f the forearm With this in mind Duben recc mmends his boxing gl ve plaster landage which extends t all the finger tips In the last year we have applied the pla ter to the mid lle of the upper arm and l elieve that we can see a quicker uni n particularly in the inve terate cases than earlier where we applied the plaster to the ell w accor ling to B hler Our eries does n t permit a review f thi difference h wever sinc we nly gradually transferred tc the longer plaster landage When h wever the treatment of fractures cf the navicular bcne presents such a great prcl lem that at any rate 8 different methods f perati n are de cribed the pr l lem well kn wn tc surge ns is held respon il le i e that many fracture are nct rec gni ed in the earlier stages —partly because many fracture cann t l e seen n X ray pictures taken just after

trauma—partly because many cases are regarded by both doctor and patient as a simple sprain which will heal spontaneously Of our 35 patients with inveterate fractures 11 were X rayed immediately with negative results If the fracture for one reason or another is not recognised until a late stage the X ray will show a quite manifest pseudarthrosis with sclerosed fracture lines and cystic rarefaction Conservative treatment may be tried but will take often six months or a whole year and many authors therefore quickly adopt operation

Amongst the published methods of operation it must be mentioned that P G K Bentzon together with Randlov Madsen in 1944 announced his method which by means of fascia plastics between the fracture fragments transforms the pseudo arthrosis to a nearthrosis In 1954 Perey announced 15 cases of follow ups—14 of which had restarted work—10 without subjective trouble while 4 had trouble

The intra osseous method of bone graft originally announced by Adams and Leonhard in 1928 has many advocators Out of 20 patients Berben has 13 especially good 4 good and 3 poor A Hoff has 44 united out of 49 Murray 96 out of 100 Palmer and Widen 28 out of 28 Stewart 3 out of 5 and Scaglietti and Perrazini 10 out of 10

The Matti operation consisting of scraping out the bone and the introduction of spongious bone transplant has been used b Hueck and Bauer who obtained union in 4 out of 7 by Fehr who obtained union in 3 out of 6 and by Russe who states 80-90 union

Geisendorfer s metal wire osteosynthesis discovered by means of a case in which a drill wire broke resulted in union for Geisendorfer in 16 out of 21 and for Lindvall in 5 out of 6 while a screw osteosynthesis used by McLaughlin showed no union in 5 inveterate cases only union when used in fresh cases

Different authors have removed either parts of the bone (Aleman 1937 and Palmer 1942) or the whole bone e g. Badgley and Hayes or removed the styloid process of the radius (Smith and Friedman Badgley and Hayes Decoues and finally Hoff)—in the case of the latter as a supplement to the bone graft operation

Extirpation of fracture fragments of the navicular bone or of the whole of the navicular bone shows poor results and can be assumed to have been abandoned

Finally infcrati according to Beck is reported as a surgical procedure The method has not won so many supporters as for example the bone graft method indeed Palmer wrote even in 1942 that Beck drilling must be discouraged since he is afraid that in cases of cyst formation in the bone it can bring about the collapse of the whole bone On the Danish side the method has been employed in 10 cases by hJ Andersen and F Therkelsen They obtained union in 4 cases The best results are from S t-Hall and Haldeman who obtained union in 5 out of 6 In addition Schnek obtained union in 1 out of 3 and Stewart in 1 out of 2 while Aleman had no union in any of his 6 patients operated on

Summary and conclusion

In a series consisting of 51 fresh and 35 inveterate cases of fracture of the navicular bone of the hand infcrati according to Beck was undertaken in 12 patients In 8 there was certain osseous union in 2 partial effacement of the fracture line and in 2 no union occurred as their after treatment was broken off through home visiting

One patient was treated by X ray and the result achieved with a smooth nearthrosis recalls somewhat that achieved by a Bentzon operation

remaining 9 and the 3 non united patients from the gr up of fre h ca es were surgically treated and the present study therefore concerns the e 12 patients perated on and the patient treated by X ray

Group 3 X ray treatment of pseudoarthrosis of the navicular bone

An ensign aged 25 who first sought treatment 12 months after trauma On X ray examination pseudarthrosis was found with irregularly sclero ed fracture lines He was treated with a total of 375 r and has now been examined 4 years after c nclusion of treatment Subjectively minimal pain is rep rted when w rking hard and objectively a m bility am unting to a that of the healthy hand was found

Hand grip 75 against 170

On X ray examinati n a nearthr sis can now be een with sm other g ll king articular surfaces and no sign of secondary arthr sis thus recalling the result f l lowing a Bentzon operation

As the tables sh w certain osseous uni n arc e in 8 f the 12 patient Mobility in the wrist joint was alm st normal e pecially in the ca e f tho e ol erved over a long period

In 2 patients the fracture uni n is designated as partial but b th the e patients are working and it seems to them that the hand improved after perati n They were both only ol served f r 3 m nths after the c nclu i n f treatment s further im provement is still possible

In 2 patients no union occurred In re pect of b th of the e patients it may be said that the length of after treatment i uncertain and wa nly carried out by us for about 2 m nth They were sent h me and the department had n pp rtunity therefore to direct the after treatment itself

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GRIP RECONSTRUCTION OF THE HAND WITH TRANSFER OF SMALL NEUROVASCULAR ISLAND FLAPS

by *Erik Moberg* (Gothenburg, Sweden)

By means of previous studies I have been able to show that the functional value of a hand grip is fundamentally due to the fact that the surfaces which contact each other in the grip possess normal and full sensibility called tactile gnosis Here one must clearly differentiate between this quality of sensibilit and the lower degrees of sensibility which can be determined by the customary examinations with cotton wool and pinprick These examinations have as regards the hand no value from a practical point of view For with these methods one cannot differentiate between paresthesia and tactile gnosis

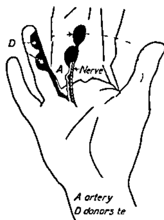


Fig 1
Transfer of sen ibility carrying skin hanging on nerve and artery from ring finger t a thumb without useful sensibility The index and long finger are covered

When a grip has to be reconstructe l one of the most important procedure is t upply the gripping surfaces with normal sensation if such is lacking I r thi purp e I began as early as ten years ago to transfer to such surfaces small i lands f suitable skin still in c ntact with good nerve an l artery supply The practical results have been striking

Starting from c mplicated reconstruction cases demonstrating the principle the u e of the technique wa hown in a eri f increa ingly more simple e As an example of the latter may be menti ned the imple u f d rsal kin with n rmal ens ry function br ught t the v lar surf ce in fing r amputati n an l the covering of thumb an l finger pulp with kin fr m m re proxim l dl cte l free with nerves and ve el the kin ver quite simple ul l e tret he l t 2 cm in a listal d recti n an l afterwar l with this l ngthening c ul l be ut re l into pla e again giving cov r with sen il ility t th gripping urface

The principle ha many a lapt ti n in ryd y surg ry esp cially in the treat ment of var ou f rm f a ute l n l injuri Every squ are centim tre f kin with its n rmal sen il ility retain l ught t l a ell ere f r lat r r c n tru ti n

LUXATIO COXAE CONGENITA: DIAGNOSIS AND TREATMENT IN NEWBORNS

By Ingulf Medbo (Alesund, Norway)

Over a three year period a consistent clinical examination for hip joint dysplasia was carried out on 3,242 newborns in a district in which the incidence of dysplasia seemed uncommonly high.

Wherever it was thought, depending on clinical examination, that pathological hip joints were present, X-ray examination was also undertaken. In all 50 children with probable hip joint dysplasia at birth were found.

Treatment was performed with Frejka's cushion splint. In individual cases a short period of immobilisation in a plaster cast was also prescribed.

Clinical and X-ray control of all patients was adopted in the treatment period.

Clinically and radiologically normal hips were achieved in 49 of the 50 patients. In the remaining patient slight subluxation was present in one hip when the examination was concluded. The cause of the failure in treatment of this patient is specially discussed.

The experience believed to have been acquired on the basis of this material may be summed up as follows:

1. In the neonatal stage clinical examination of the hip joint is superior to the X-ray. It is not until the epiphysis is visible on the X-ray that this method of diagnosis reveals something more than the clinical examination.

2. For the great majority of patients in this age group Frejka's cushion splint gives satisfactory immobilisation in a favourable position. It seems to trouble the patient but little. It is easy for the mother to adjust and the treatment can be given outside the hospital.

3. When treatment of a hip joint dysplasia is commenced in the newborn stage in the great majority of cases normal hip joints will be achieved before the child begins normally to put weight on the lower extremities. The treatment can therefore be performed during a period in which the physical and mental development of the child is affected to the least possible extent.

OUR FURTHER EXPERIENCE IN THE TREATMENT OF CONGENITAL HIP JOINT DISLOCATION IN NEWBORNS

By Sophus von Rosen (Malmö, Sweden)

At N.O.F.'s Congress in Lund-Malmö two years ago I brought up the following questions for discussion:

1. What is the cause of congenital hip joint dislocation?
2. Is the dislocation always present at birth?
3. Can the dislocation always be diagnosed immediately after birth?
4. How long is the treatment required?

Today I shall begin with questions two and three and answer them simultaneously against the background of our continued experience. This experience is based on 37 cases of congenital hip joint dislocation out of 24,000 newborns. This is an incidence of 0.15 ... In all but one case the diagnosis was made during the first ... after birth. The case which spoils our statistical perfection is that of a girl born in Malmö while the mother was spending the summer in the town. The girl had ...

the first day after birth and was transferred to the Children s Hospital As a result of this the hip joints were not examined according to routine The dislocation was discovered when the girl began to walk and then limped with the one leg This case excepted the questions whether the dislocation is already present at birth and whether the diagnosis can already be made at this time may be answered in the affirmative

Question no 4 How long is the period of treatment required?

The answer to this question remains as before up to three months In some cases the fixation period was shortened to as little as 6 weeks Redislocation did not occur in any ca e and hitherto we have had no case showing Perthes like changes or subluxation

I shall deal especially with the question about the cause of congenital hip joint dislocation

Our fine treatment results have persuaded us more and more to doubt that the cause of the dislocation is a congenital dysplasia of the hip joint The constantl repeated observation that the reduced hip joints are felt to be quite stable as soon as a few weeks have passed even earlier if they are reduced and fixed in the reduced position during the first days after birth —this observation also argues against the above theory

At the X ray examination of a dislocation case in September 1959 my radiological colleague Lars Andrén made a ver interesting observation He found a looseness present not only in the hip joint but also in the pelvic joints On picture taken in Lauenstein s position with the legs apart and pressed against the midline of the bod the difference in distance between the proximal ends of the femoral diaphyses was 10 mm The difference in symphysis width was 3 mm on the respective pictures Similar observations were made later in 5 cases of dislocation while 70 normal cases only showed a difference in symphysis width of 1½ mm at the most

Could the cause of the congenital hip joint dislocation be a primary looseness of the hip joints and to what could such a looseness in turn be attributed? It is a logical step as regards the looseness in the symphysis joints to mak a comparison with the relaxation in the pelvic joints of the pregnant woman which occurs in connexion with delivery It is hardly to be doubted that this is conditioned by hormones

In newborns it is known through *Diczfalusy* s re earch that oestriol is present in the urine during the first week of life *Deblieck* and *Schwers* have also sh wn in their research that the urine from girls contains more oestriol than that from boys Would it be p ssible that the newborns with congenital hip joint dislocation diverge in these respects from normal newborns In collaboration with the Women s Clinic in Malm hormone analyses are now made in our new dislocation cases By good fortune it has turned out that just when this problem arose it became technically possible for us to carry out the e hormone analyses

The preliminary results of these investigations revealed that the amount of conjugated oestriol excreted was about the same as in the control group but the amounts of oestrone and oestradiol-17 β were definitely larger

I shall n t now give an account of this research in detail It will be reported in an ther c ntext If the progress it seems to promise is maintained then congenital hip j int dislocation will in future be more of an endocrinal than an orthopaedic disease The task of the orthopaedic surgeon will merely be confined to seeing that the relaxe l hip j ints are fixed in the reduced position until they are stabilised It

alread appears to me to be a serious sin of omission if every possibility is not examined of discovering these cases immediately after birth and of starting treatment at once

DISCUSSION

M Fellander (Stockholm) and *A Langenskiold* (Helsingfors)

THE POSITION OF ORTHOPAEDICS IN MODERN MEDICINE

by *G von Bauer* (Malmo Sweden)

(Abstract)

Like in other countries and other areas of medicine Swedish Orthopaedics is drastically shifting its emphasis from cold" orthopaedics practiced in isolated institutions to embrace metabolic skeletal disease and fracture surgery practiced in close co-operation with other specialities Examples of dwindling diseases are tuberculosis and sequlae to poliomyelitis osteitis club foot and congenital dislocation of the hip Examples of increasingly severe problems are osteoarthrosis and various traumatic conditions

The changing pattern of disease is an effect of political social demographic and medical factors The challenge of this situation can be accepted by orthopaedic surgeons only if they are willing to change presently accepted standards for training in orthopaedics (Published in Svenska Lakartidningen 5 2684 1960)

DISCUSSION

Erik Moberg (Gothenburg Sweden)

We should be grateful to Docent Bauer for bringing forward the problem for discussion Trauma is without doubt here to stay It will be one of the great disease groups of the future by the side of psychiatry circulation disturbance and perhaps dermatology *Someone* must treat it

The tasks of *orthopaedics* have diminished, for tuberculosis has almost been eliminated poliomyelitis is strongl on the decline and the suppurative conditions are considerably reduced in number Apart from trauma new problems have arisen Laine and Vainio in Finland have shown that every third patient with chronic polyarthritis can be aided more through surgery than in any other way Hand *surgery is far from being as well practised as one could desire* with our present knowledge We do not possess today surgeons who are capable of accomplishing these tasks but we can train them Today I shall only speak about trauma We have to include quantitative factors geographical factors and finall the question of personal ability

As far as the quantitative factors are concerned a committee has been set up t inquire into the organisation of traumatology in England From one of the leading members I know that one of fundamental tasks of this committee is to recommend to the small hospitals that they should cea e to take care of accident cases In our countries a good department of traumatological surgery of the extremities with *fractures cannot be organised with fewer staff* than six doctors which corresponds

to approximately 100 beds Smaller departments cannot maintain a service for 24 hours a day with adequate quality—even so the burden is heavy Bauer statement it is not the surgeons who will swallow up the fractures but it is the fractures which will swallow up the surgeons" is absolutely correct One of three of our operations is acute

The geographical factors are completely different in different parts of our countries To have the same organisation in the great cities—around Copenhagen and Stockholm—as in north Sweden and Norwa is out of the question Different solutions must be adopted for different areas

In the end personal ability remains a decisive factor One must realise clearly that the time is past when one learnt fracture surgery by studying for some years at a clinic for general surgery Wherever one s training is obtained—and this applies to general surgeons orthopaedic surgeons and plastic surgeons to an equal extent—a supplementary training by no means insignificant will become necessary for whoever shall tend the fractures which we admit today The skin problems dominate here as never before If they cannot be solved then one is not capable either of being responsible for the care of the fractures The skin problems must be solved at once yet nowhere do plastic surgeons wait up at night for the stream of accident cases which rolls in Trauma must be lived with as it were if a surgeon is to be capable of tending these cases

The field is so large and the problems are so many that a treatment which is adequate can be scarcely imagined without collaboration from all the departments concerned It is certainly very desirable that the orthopaedic surgeons should make in all sincerity and effectiveness a vastly greater effort than they have done previously A train is standing at the station It will be leaving because it has an urgent task Who will travel with it?

FROM THE ORTHOPAEDIC DEPARTMENT (HEAD PROFESSOR CARL HIRSCH) ACADEMIC HOSPITAL UNIVERSITY OF UPPSALA SWEDEN

AN EXPERIMENTAL STUDY ON THE USE OF NAILS AND BOLT SCREWS IN THE FIXATION OF FRACTURES OF THE FEMORAL NECK

By

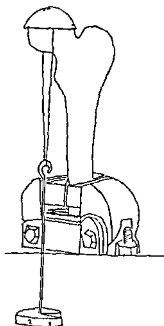
ALFREDO BRODETTI

The great variety of nail and screw like appliances that are now available for use in the fixation of fractures of the femoral neck indicate that confusion still exists when a choice is to be made of the most suitable internal splint to maintain the reduction of the fracture until the healing process is completed

The literature on both the clinical and surgical aspects of this subject is large but there are relatively few papers devoted to the experimental investigation of the effects of internal fixation in fractures of the femoral neck The work of *Kotrnetz* (13) is the first in this field His study was carried out in only ten femoral necks which after division were fixed with Smith Petersen nails *Lehman* (14) also using Smith Petersen nails analysed the angle of inclination of the fracture line and the wedging of the fragments in four specimens Both these studies were rather unconclusive due to the small number of experiments on which they were based Experimental studies were also reported on the Putti screw (3) and on the Compere pins (5) *Harmor Baker & Reno* (9) published the first extensive investigation on the subject They tested 12 different types of appliance in the fixation of fractures in 242 femoral necks However in their experiments the loading forces were applied to the femoral heads in such a way that the fracture surfaces were impacted rather than distracted

In almost all the experiments reported in these papers the weight bearing capacity (W B C) of the particular metallic device used to obtain fixation of the specimens was stressed In the present work emphasis has been shifted from the strength of the device to that of the

Fig 1
Loading arrangement used for the first series of experiments Via a metal bowl weights of 2 5 kg each to a maximum of 20 kg were suspended from the femoral head



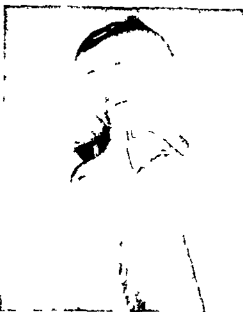


Fig 2
The strain gauge applied on the medial aspect of the femoral neck The dotted line indicates the location of the experimental fracture

experimental fracture in terms of its W B C (i e the relation between deflection and load) when fixed with a given type of appliance

While admitting that experimental techniques do not reproduce exactly the conditions of the living human it was felt that some evidence could be presented in favour of the superiority of one or other of these devices in maintaining the reduction of experimental fractures of the femoral neck

METHODS AND MATERIALS

The equipment used in the experiments (11) included the following

1 A loading apparatus giving an increasing load which can be measured continuously Weights of 2 5 kg each suspended from the femoral head via a metal bowl (Fig 1) until a maximum of 20 kg was reached were used An Amsler Hydraulic Machine was used for heavier loads This machine is provided with a dial the indicator of which

Fig 3
Loading arrangement for the second series of experiments in which the Amsler Machine was used *The lower end of the specimen firmly fixed in the vice rests on a steel "tooth edged" surface to ensure a better grip*





moves clockwise giving the amount of progressive ... to the material under test When the load applied ... breaking stress of the material the indicator ... return to zero following the anti clock wise ... *mains on the reached point*

2 Strain gauges (Philips Type P R 9211 B ... K 1 88–1 5 %) *applied on the medial aspect of* the line of the experimental fracture (Fig 2)

3 Direct Reading Measuring Bridges (Phi... readings of the deflection caused by the incre...

The specimens consisted of the upper third ... the surrounding soft tissue had been dissecte... femoral shaft 25 cm from the top of the ... end was kept constant The distal end of th... was placed in a specially adapted vice (Fig ... firm fixation and accuracy to obtain the ... ment The specimens were radiographed ... *ments*

Vertical loading was used with its d... shaft This type of loading was chosen

1 It is the easiest to reproduce exp...

TABLE I

Experimental details of the 22 specimens of the first series

R = Right L = Left S G = Strain gauges H M = Hydraulic Machine

Case No	Age	Sex	Side Type of appliance	Type of measurement	Site of the appliance Additional comments	W B C in
1/1	70	F	R Nail	S G	Nail in valgus	30 %
2/45	72	F	L Nail	S G	Fracture reduced in valgus	22 %
3/2	81	F	R Nail	S G	Fracture reduced in valgus	28 %
4/3	77	M	R Nail	S G	Nail in the Neutral Zone	24 %
5/3	77	M	L Nail	S G	Nail in the Neutral Zone	29 5 %
6/4	65	M	R Nail	S G	Nail in the Neutral Zone	23 %
7/5	78	M	L Bolt screw	S G	Screw in the Neutral Zone	39 %
8/7	66	M	R Bolt screw	S G	Screw in the Neutral Zone	41 %
9/8	81	F	R Nail and Bolt screw	S G + H M	Specimen with severe osteoarthritic changes tested with both a nail and a screw 1st Exp Nail fixation 2nd Exp Screw fixation This specimen is not included in the results	 6 % 19 %
10/9	28	M	R Bolt screw	S G	Fracture reduced in valgus	38 %
11/9	28	M	L Bolt screw	S G	Screw in valgus	37 %
12/50	68	M	R Nail	S G	Fracture reduced in valg[illegible]	30 [illegible]

						of the bolt	36
14/11	50	M	I	Bolt screw	S C	The screw in the same position as specimen 13/11 No valgus deformity resulted for the tightness of the bolt was not extreme This specimen is not included in the results	34 5 %
15/12	82	F	R	Bolt screw	S C	Screw in the Neutral Zone	44 %
16/12	82	F	L	Two bolt screws	S C	Three types of experiments	
						A) The superior screw in varus only	34 %
						B) Two screws the superior in varus the inferior in valgus	40 5 %
						C) The inferior screw in valgus only	37 %
17/13	79	F	R	Two bolt screws	S C	Same as the preceding specimen	
						A)	33 %
						B)	42 %
						C)	36 %
18/13	79	F	L	Two bolt screws	S C	Same as the preceding specimen	
						A)	31 %
						B)	39 5 %
						C)	30 5 %
19/53	73	M	R	Two bolt screws	S C	Three types of experiments	
						A) The inferior screw in valgus only	35 %
						B) Two screws the superior in varus the inferior in valgus	40 %
						C) The superior screw in varus only	34 %
20/14	33	M	L	Bolt screw	S C	Screw in the Neutral Zone Increasing tightness of the bolt the W B C values increase too	A 47 %
							B 50 %
							C 52 %
21/15	[illegible]	F	R	Nail	S C	Nail in valgus	33 %
2/15	[illegible]	F	L	Nail	S C	Fracture reduced in valgus	29 %

TABLE II

Experimental details of the 48 specimens of the second series

R = Right L = Left H M = Hydraulic Machine S G = Strain gauges

Case No	Age	Sex	Side / Type of appliance	Type of measurement	Site of the appliance / Additional comments	W. B. C. in %
23/16	54	F	R	H M	Breaking point 800 kg	
24/16	54	F	L Nail	H M	Nail in the Neutral Zone Fracture discontinued at 265 kg	33 %
25/17	77	F	R	H M	Breaking point 880 kg	
26/17	77	F	L Bolt screw	H M	Screw in the Neutral Zone Fracture discontinued at 385 kg	43 5 %
27/18	68	F	R	H M	Breaking point 710 kg	
28/18	68	F	L Nail	H M	Fracture reduced in valgus discontinued at 190 kg	26 5 %
29/19	73	M	R	H M	Breaking point 1000 kg	
30/19	73	M	L Bolt screw	H M	Screw in valgus Fracture discontinued at 365 kg	36 5 %
31/20	66	F	R	H M	Breaking point 920 kg	
32/20	66	F	L Bolt screw	H M	Screw in valgus Fracture discontinued at 350 kg	38 %
33/20	70	F	R	H M + S G	Breaking point 370 kg	
34/22	70	F	L Bolt screw	H M + S G	Screw in the Neutral Zone Fracture discontinued at 170 kg	46 %
35/23	71	F	R	H M	Breaking point 680 kg	
36/23	71	F	L Nail	H M	Nail in the Neutral Zone Fracture discontinued at 165 kg	24 %
37/24	83	F	R	H M	Breaking point 710 kg	
38/24	83	F	L Bolt screw	H M	Screw in the Neutral Zone Fracture discontinued at 365 kg	51 %
39/25	71	F	R	H M	Breaking point 870 kg	
40/25	71	F	L Bolt screw	H M	Screw in the Neutral Zone Fracture discontinued at 380 kg	44 %
41/26	76	F	R	H M + S G	Breaking point 630 kg	
42/26	76	F	L Nail	H M + S G	Nail in the Neutral Zone Fracture discontinued at 215 kg	14 %

43/27	70	M	R	H M	Breaking point [illegible]	
44/27	70	M	L Bolt screw	H M	Screw in varus Fracture discontinued at 305 kg	36
45/28	72	F	R	H M	Breaking point 720 kg	
46/28	72	F	L Bolt screw	H M	Screw in varus Fracture discontinued at 225 kg	31 %
47/29	73	F	R	H M + S C	Breaking point 980 kg	
48/29	73	F	L Nail	H M + S G	Nail in valgus Fracture discontinued at 285 kg	32 5 %
49/30	76	F	R	H M	Breaking point 920 kg	
50/30	76	F	L Nail	H M	Nail in valgus Fracture discontinued at 285 kg	31 %
51/31	73	M	R	H M	Breaking point 900 kg	
52/31	73	M	L Nail	H M	Nail in valgus Fracture discontinued at 210 kg	26 %
53/32	71	F	R	H M + S C	Breaking point 680 kg	
54/32	71	F	L Bolt screw	H M + S C	Screw in varus Fracture discontinued at 215 kg	31 5 %
55/33	80	F	R	H M + S C	Breaking point 910 kg	
56/33	80	F	L Nail	H M + S C	Nail in varus Fracture discontinued at 210 kg	23 %
57/34	68	M	R	H M	Breaking point 470 kg	
58/34	68	M	L Bolt screw	H M	Screw in varus Fracture discontinued at 160 kg	34 %
59/35	62	F	R	H M	Breaking point 780 kg	
60/35	62	F	L Nail	H M	Nail in varus Fracture discontinued at 195 kg	25 %
61/36	70	F	R	H M	Breaking point 690 kg	
62/36	70	F	L Bolt screw	H M	Fracture reduced in valgus discontinued at 255 kg	37 %
63/37	61	M	R.	H M + S C	Breaking point 840 kg	
64/37	61	M	L Bolt screw	H M + S C	Fracture reduced in valgus discontinued at 295 kg	35 %
65/38	59	M	R.	H M + S C	Breaking point 9 0 kg	
66/38	59	M	L Nail	H M + S C	Fracture reduced in valgus discontinued at 295 kg	32 %
67/39	69	F	R.	H M	Breaking point 580 kg	
68/39	69	F	L Bolt screw	H M	Fracture reduced in valgus discontinued at 225 kg	39 %
69/59	66	F	R	H M + S C	Breaking point 675 kg	
70/59	66	F	L Bolt screw	H M + S C	Screw in valgus Fracture discontinued at 250 kg	37 %

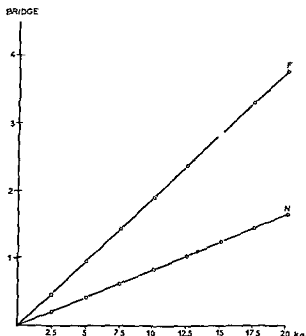


Fig 4

W B C diagram of specimen 15/12 recorded by means of a straingauge N = the normal W B C of the specimen F = the W B C of the specimen fractured and fixed with a screw F is 44 % of N

type of loading most similar to living conditions The individual standing on both legs with the help of the locking of the knees of the hips and of the lumbar spine joints requires little muscle power to maintain his balance (2) And so using a vertical loading the complex and important role played by the muscles in the mechanics of the hip joint is partially reduced

b Vertical loading through the calcar femoralis is transmitted to the medial cortical bone of the femoral neck (2 12 15) thus permitting better detection by means of strain gauges of the magnitude of deformation occurring

For the purpose of comparison in this study experimental fractures were produced with a hand saw (throughout this paper fracture refers to the artificial division of the femoral neck) Subcapital fractures with a direction perpendicular to the axis of the femoral neck were obtained A radiographic control assured that they were identical Moreover variations of the cervical angle of the femoral neck were taken into consideration and the limits were set within 124 and 131

Specimens that at the radiographic control were found above or below the limit were eliminated

Fresh specimens removed at autopsy were used The results obtained in 70 specimens will be reported here Those used for testing the experimental arrangements or eliminated because they did not meet the experimental requirements are not considered

The 70 femora were obtained from 40 cadavera Of these 25 were females and 15 malees Their ages ranged from 28 to 83 years the average being 70 years

Two types of experiments were undertaken

1 The normal W B C of a group of 22 specimens (Table I) loaded between 2 5 and 20 kg was recorded by means of strain gauges (Fig 4 N) These femoral necks were then fractured as described above The fragments of the head and neck were aligned and fixed with either a nail (10 cases) or a bolt screw (13 cases)[1] The specimens then were again subjected to loading with the same technique used for the first test Deflections were recorded (Fig 4 F) and the values from this second test were expressed as a percentage of the normal W B C derived from the first experiment

2 In a second group of 48 specimens (Table II) the 24 right femoral necks were submitted to vertical loading in the hydraulic machine until fracture occurred In Fig 5 is shown the curve of deflection of a normal femoral neck recorded througt strain gauges applied on its medial aspect This specimen was subjected to vertical loading in the hydraulic machine until fracture occurred at 950 kg This amount of laod indicated by the arrest of the marker on the dial of the Amsler Machine is the point of breaking stress which corresponds to the W B C of this femoral neck On this basis the figures obtained at the breaking point of the right sided specimeens were assumed as the normal W B C for the particular pair of femoral necks under investigation

The 24 left sided femoral necks were prepared with a fracture fixed with one or other of the devices under consideration (10 nails and 14 bolt screws) These were then tested in the hydraulic machine the load being increased until discontinuity of the "fracture occurred By discontinuity here is meant the end point of the test given by the arrest of the marker of the dial of the Amsler Machine (Fig 5) The amount of load required to discontinue the "fractures of the left sided specimens was recorded as the W B C of the fixed "fractured femoral neck

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[1] Specimen 9 8 was tested with both the nail and the bolt screw

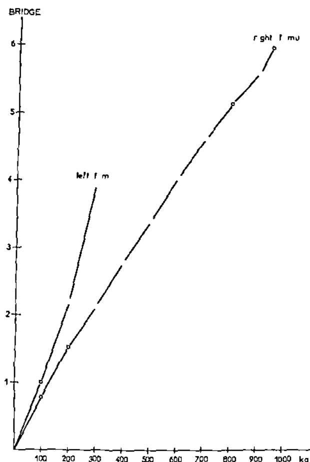


Fig 5

W B C diagrams of specimens 65/38 and 66/38 recorded by strain gauges The right femur (65/38) was loaded under the hydraulic machine until fracture occurred at 950 kg This amount of load was assumed as the normal W B C of this pair of femoral necks The left femur was fractured and fixed with a nail Loaded under the hydraulic machine the fracture was discontinued at 295 kg This amount of load *representing the W B C of the fractured and fixed femur is 32 % of the* normal W B C

These values were then estimated as to percentage of the normal W B C of the right femoral neck

According to Hooke s law the relation between deflection (strain) and load (stress) on the whole ran a straight line (11 2) Therefore the determinations would give the same percentage values regardless of the weights used in loading the specimens In Chart 1 is shown that

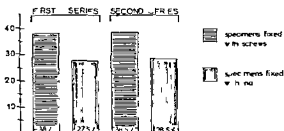


Chart 1

The comparison between the average W B C values obtained by means of strain gauges in the first series of experiments (11 specimens fixed with bolt screws 9 with nails) and the average W B C values obtained in the second series of experiments (14 specimens fixed with bolt screws 10 with nails) using the hydraulic machine

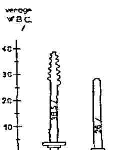


Chart 2

The comparison between the average W B C of 25 fractured femoral necks fixed with bolt screws and the average W B C of 19 fractured" femoral necks fixed with nails

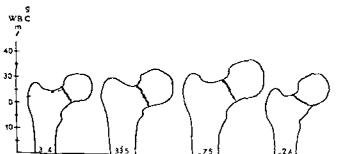


Chart 3

The differences among the average W B C values according to the various positions of the appliances and to the reduction of the fractures From left to right varus position valgus appliance in the neutral zone fractures" reduced and fixed in valgus



Fig 6

Specimen 58/34 Breaking point of the right femur at 470 kg Bolt screw in varus in the left femur (a) Fracture discontinued at 160 kg (b) W B C 34 %

the average values obtained by means of strain gauges in the first series of experiments and those obtained by loading the specimens in the hydraulic machine in the second series are approximately the same Moreover in some of the experiments of the second series strain gauges were used too (Table II)

25 specimens were tested with a bolt screw and 19 with a nail These were placed in different positions and sites in the specimens viz in varus valgus and along the centre of the neck and femoral head This last position is referred to as the neutral zone of the femoral neck and its significance will be discussed later In addition a group of the fractures were reduced and fixed in valgus

On specimens 9/8 16/12 17/13 18/13 19/53 20/14 of the first series of experiments more than one test was conducted However one test only was considered in the results the test performed first

Specimens 9/8 and 13/11 (Table I) being only indicative were not included in any of the groups of the results

RESULTS

The average W B C for the 25 fractures fixed with bolt screws was 38 5 % with a maximum value of 51 % and a minimum value of 31 %

The average W B C for the 19 fractures fixed with nails was 28 % (maximum value 34 % minimum value 22 %) (Chart 2)



Fig 7

Specimen 50/30 Breaking point of the right femur at 970 kg Nail in valgus (a) "Fracture" discontinued (b) at 285 kg W B C. 31% In this specimen the obliquity of the nail results in an eccentricity of its medial end thus lowering the holding power

The following results are grouped according to the different positions in which the fixing devices were placed in the specimens (Chart 3) The identifying number of the specimens reported for each group corresponds to Tables I and II

VARUS

In this group the appliance was placed in a varus position 7 specimens (16/12A 17/13A 18/13A 44/27 46/28 54/32 58/34) were fixed with bolt screws (Fig 6) 2 specimens (56/33 60/35) were fixed with nails The average W B C was 31 % Maximum value 36 % minimum value 23 %

VALGUS

Five specimens (11/9 19/13A 28/19 30/20 70/59) were fixed with bolt screws and 5 specimens (1/1 21/15 48/29 50/30 52/31) were fixed



Fig 8

Specimen 34/33 Breaking point of the right femur at 370 kg Bolt screw in the neutral zone (a and b) Fracture dis ontinued at 170 kg (c) W B C 46 %



Fig 9

Specimen 5/3 tested with a strain gauge Nail in the neutral zone W B C 29 5 %

with nails (Fig 7) The appliances were placed in contact with the inferior cortex of the femoral neck The average W B C was 33 5 % Maximum value 38 % minimum value 26 %

NEUTRAL ZONE

Eight specimens (7/5 8 7 15/12 20 14A 26/17 34/22 38/24 40/25) were fixed with bolt screws (Fig 8) Six specimens (4/3 5/3 6/4 23/16 36/23 42/26) were fixed with nails (Fig 9) The average W B C of the group was 37 5 % Maximum value 51 % minimum value 22 %

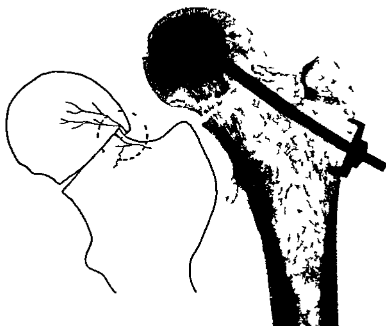


Fig 10

Specimen 64 37 "Fracture of the left femur reduced in valgus Breaking point of the right femur at 840 kg Fracture discontinued at 295 kg W B C 32 % The drawing shows how the reduction in valgus and the impaction can interfere with the lateral epiphyseal vessels

"FRACTURES REDUCED AND FIXED IN A VALGUS POSITION

Five specimens (10 9 13/11 62/36 64/37 68/39) were fixed with bolt screws (Figs 10 and 11) Six specimens (2/45 12/50 3 2 22/15 28/18 66 38) were fixed with nails The average W B C was 32 % Maximum value 38 % minimum value 22 %

DISCUSSION

The average W B C of the fractures fixed with bolt screws (38 5 %) compared with that of those fixed with nails (28 %) leaves little doubt that the bolt screw is mechanically more efficient in fixing and holding these "fractures" reduced under the conditions of the experiments These values however are only a comparison between the two devices and do not consider the position occupied by them

The tests conducted on specimen 9 8 (Table I) give a further de-



Fig 11

In (a) specimen 13/11 tested with a strain gauge The reduction in valgus of the fracture was obtained by exaggerating the tightness of the bolt with the screw placed slightly eccentric in the head W B C 36 % In (b) specimen 14/11 The screw in the same position as in specimen 13/11 No valgus reduction resulted for the tightness of the bolt was not extreme

monstration of the better experimental W B C of a fractured femoral neck fixed with a bolt screw The specimen with severe osteoarthritic changes was preleved from the cadavera of an 81 year old female *According to the technique described for the first series of experiments* the normal W B C was recorded Then a fracture was produced and was fixed with a nail The specimen was loaded again and 12 5 kg were sufficient to discontinue the fracture as shown in Fig 12 a The W B C of the nailed fracture was 6 % After removing the nail a bolt screw was replaced to fix the fracture The specimen remained connected to the measuring bridge through the strain gauges was reloaded under the hydraulic machine in order to have a possibility of higher loading This time discontinuity of the fracture (Fig 12 b) occurred at 85 kg and the W B C deduced from the diagram was 19 % These two W B C values are the lowest of all and the severity of the osteoarthritic changes are responsible for this considerable difference

When either the nails or the bolt screws were inserted in a varus position the resultant average W B C (31 %) of the fixed fractures *was among the lowest At any rate this value is higher* than one would expect considering that this is an unsound position from a mechanical



a b

Fig 12

Case 9 8 Right femur with severe osteoarthritis The fracture was firstly fixed with a nail (a) and a strain gauge was applied Discontinuity occurred at 12 5 kg W B C 6 The nail was replaced by a bolt screw (b) and the specimen still connected through the strain gauge to a measuring bridge was loaded under the hydraulic machine Discontinuity of the fracture occurred at 85 kg W B C 19 %

point of view Very likely the high average W B C obtained was due to the fact that more bolt screws (7 specimens) than nails (2 specimens) were used Therefore the average value obtained in this group may indicate trends but is not statistically significant Besides the mechanical disadvantage a device entering the femoral neck and head in varus is very likely to damage the important lateral epiphyseal vessels (4 17) This would increase in the living the risk of aseptic necrosis of the femoral head

The results obtained when the fixative devices were inserted in a valgus position confirmed the findings of *Compere Wallace & Lee* (5) These authors compared the differences in the fixation of fractures when wires were inserted parallel to the axis of the neck of the femur on one side and in a very oblique direction on the other side On the average they found that the wires inserted parallel to the neck axis would resist a load of 338 2 kg but only 205 kg if they had been inserted obliquely that is in a valgus position

If a device is inserted into femoral neck in a valgus position the tip may well fail to meet the femoral head s central point This has been shown to be its hardest point (8 18) (Fig 15 b) Should the tip of the



Fig 13
Injected specimen showing how the tip of the valgus appliance ends in the area of femoral head occupied by the lateral epiphyseal vessels (arrows)

device enter the periphery of the sphere of the head it is in a bad position for the following reasons

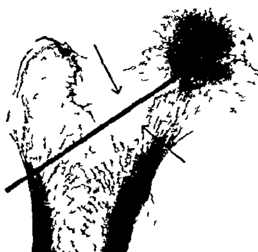
1 It can no longer prevent eccentric rotation of the head fragment
2 The holding power of the bone at the periphery of the femoral head is low
3 The lateral epiphyseal vessels are likely to be damaged (Fig 13)
4 An appliance taking a very oblique course because of the normal anteversion of the femoral neck will be prone to be posterior in the neck thus damaging one of the main supporting systems arising from the calcar femoralis (10)

The best figure for W B C (37 5 %) was obtained with the appliance in the neutral zone This corresponds to the median of the Ward s triangle (Fig 14) between the two trabecular arches which are the internal weight bearing system of the femoral neck

In an intact femoral neck under vertical load these two trabecular systems provide the 30 % of the W B C of the whole femoral neck (12) If the reduction of the fracture is anatomical the weight bearing system of the femoral neck is restored almost in its entirety A fixative device inserted in the neutral zone well anchored in the strong centre

Fig 15

The Ward's triangle limited by the internal weight bearing system (arrows) of the femoral neck. Its median corresponds to the neutral zone which is the weak point to be reinforced by an appliance when a fracture occurs



of the head and on the subtrochanteric cortical bone adds some strength reinforcing a natural weak point Moreover it does not destroy either of the two trabecular systems neither are important vascular channels in the central zone of the femoral neck and head (4) (Fig 15)

There seemed to be no advantage in reducing the fracture in valgus position and fixing it there The W B C of fixed fractures was found to be low (33 5 %) under these conditions The reduction in valgus of the fracture in specimen 13 11 (Fig 11 a) was obtained by placing the screw eccentric in the head and tightening the bolt more than necessary This resulted in rotation of the head fragment An anatomical reduction was obtained in specimen 14/11 (Fig 11 b) although the screw was placed in the identical position as in specimen 13 11 because the tightness of the bolt was not exaggerated

Excessive tightness of the bolt does not produce any damage when the screw is placed in the neutral zone but increases the W B C as shown in case 20 14 (Table I) This specimen was tested many times and each time the tightness of the bolt was previously augmented The result was an increase of the W B C up to a point at which the fixation reached a stabilization and no further increase was obtained

It is beyond the purpose of this paper to apply to the living bone conclusions obtained from specimens but a theoretical discussion of certain important biological considerations may be of interest

These considerations all stand against the possible advantages of fixing fractures in valgus position First of all not only from a me-

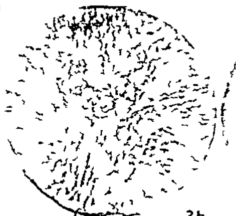


Fig 15

In (a) decalcified left femoral head of subject aged 68 after vascular injection with barium divided into slab sections Section 4 includes the point of entry of the lateral epiphyseal vessels (uppart part) and section 3 that of the inferior metaphyseal vessel (lower part) Two parallel rows demonstrate the sections of the femoral head and neck in succession from 1 to 5 prior to decalcification (b) and after decalcification (c) The trabecular arrangement can be followed in (b) in section 3 b corresponding to the centre of the femoral head the trabecular concentration is greatest Medially (sections 2 b and 1 b) and laterally (sections 4 b and 5 b) the number of trabeculae decreases The vascular pattern can be followed in (c) starting from the femoral neck (section 5 c) it can be seen that the pattern is peripheral The only artery met by a central appliance is the superior metaphyseal artery which in section 4 c crosses the bone longitudinally Note the rich anastomoses at the periphery of the section Section 3 c shows the lateral epiphyseal vessels (above) and the inferior metaphyseal vessels No important vascular formation occupies the centre of the section The rich network of the anastomoses between the











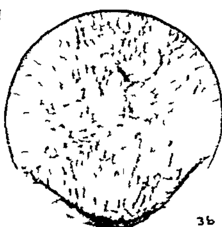


Fig 15









Fig 15

arteries coming from the round ligament and the lateral epiphyseal vessels ar shown in ?c Due t their richne s the eventual severing of some of these anast moses by the appliance is of secondary importance

chanical point of view it is important to replace the architectural elements of the femoral neck in order to have the trabeculae orientated according to their normal lines of stress Any deviation in direction or change in power acts upon the bone tending to readapt it s structure (1) These efforts in the case of a fractured femoral neck would greatly retard the healing process Conversely the forces within the limits of tolerance will stimulate the bone formation if they are applied as intensified normal forces (6) This in the living corresponds to the impact established by the bolt screw in an anatomically reduced fracture of the femoral neck

Secondly the formation of the healing callus in fractures of the femoral neck speaks for itself in favour of an anatomical reduction No periosteal callus has been found or demonstrated in the healing fracture of the femoral neck *Farkas Wilson & Hayner* (7) studying a specimen of a healed fracture observed that the new bone formation due to the healing process arose from the existing trabecular structure of the internal weight bearing system

Such a reparative process could be facilitated by replacing the components involved in their anatomical relationship and by avoiding the presence of a foreign body in the area where new bone formation is known and expected to occurr

SUMMARY AND CONCLUSIONS

1 Seventy fresh specimens of human femoral heads and necks have been examined under defined conditions of experiments

2 The tests showed that a bolt screw is a more satisfactory device than a nail in the fixation of experimental "fractures of the femoral neck

3 The best experimental position for insertion of the fixative device is in the "neutral zone" of the femoral neck following near perfect anatomical reduction of the "fracture"

4 With emphasis on the limitations implied in the fact that conditions of experimental mechanical tests on specimens are far from those in the living human some theoretical advantages of the findings have also been discussed

ACKNOWLEDGEMENTS

This work was undertaken in the Biomechanical Laboratory of the Orthopaedic Department of the University of Uppsala Sweden while

the author was holding an Assistantship there I am deeply grateful to Professor *Carl Hirsch* for his help and encouragement

The references to the *blood supply of the femoral head and neck* have been suggested by Professor *Truela* of Oxford and I must thank him for his kindness

My thanks are also due to the Stilles Werner Company of Stockholm who kindly provided the different appliances to be tested

RESUME

1 Soixante dix specimens frais de tetes et de cols de femur humain ont ete examines dans des conditions d experimentation definie

2 Les épreuves montrerent que le boulon a vis est une formule plus satisfaisante que le clou pour la fixation des fractures experimentales du col femoral

3 La meilleure position expérimentale pour l insertion du moyen fixatif est la "zone neutre du col femoral en suivant de tres pres la reduction anatomique de la fracture

4 En soulignant les limites dues au fait que les conditions des epreuves mecaniques experimentales sur des specimens sont loin de celles que l on peut pratiquer sur des etres humains il est discute des avantages theoriques de ces trouvailles

ZUSAMMENFASSUNG

1 Siebzig frische Exemplare von menschlichen Schenkelhalsen und Köpfen wurden unter bestimmte experimentellen Bedingungen untersucht

2 Die Versuche zeigten dass zur Feststellung von experimentellen Brüchen des Femurhalses eine Bolzenschraube eine zufriedenstellendere Vorrichtung ist als ein Nagel

3 Die beste experimentelle Position für die Einführung der fixierenden Vorrichtung liegt in der neutralen Zone des Schenkelhalses nach beinahe perfekter Reposition der Fraktur

4 Unter Betonung der Begrenzungen die sich aus der Tatsache ergeben dass Bedingungen in experimentellen mechanischen Untersuchungen an Präparaten wesentlich verschieden von denen beim lebenden Menschen sind werden einige theoretische Vorteile der Befunde besprochen

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FROM MARTINA HANSEN S HOSPITAL NORWAY
(HEAD JOHN K HALD M D)

ARTHRODESIS OF THE SHOULDER

A simple elastic band appliance utilising the compression principle

By

M FOSS HAUGE

INTRODUCTION

The value of compression in arthrodesis of joints as well as in the treatment of fractures has been the subject of much discussion during recent years Some authors (*Charnley* 1951 *Kaplan* 1953 and others) maintain that compression is a factor of no less importance than reposition and immobilisation Others (*Watson Jones* 1955) warn against compression and believe that it is of value only in so far as it promotes immobility of resected surfaces of cancellous bone

At Martina Hansen s Hospital we have for many years used a special kind of compression as a routine method in arthrodesis When technically possible we have employed a screw in order to obtain

1) better postoperative immobilisation and
2) better contact of bone at the place of resection than can be obtained with plaster cast alone

But the screw usually tends to become loose within a few weeks and for this reason we have since 1952 tried to incorporate and substitute *the internal fixation of a screw with sustained physiological compression* This has been done by different methods according to which joint has to be arthrodesed In arthrodesing hips and knee joints early weight bearing is encouraged *In arthrodesing the shoulder* we use a simple elastic compression together with an abduction frame and plaster shoulder spica The clinical results of this arrangement have been so encouraging that we feel justified in publishing the method

It is not proposed to discuss in detail the possible influence of compression on the osteogenesis but our opinion based on clinical observa

tions (of a large number of cases) on theoretical views and on a few histological examinations may briefly be outlined as follows

Careful compression increases the chances of obtaining bony union probably not by reason of the compression in itself but because of the more satisfactory immobilisation and the avoidance of diastasis We do not think that mechanical compression itself can accelerate osteoblastic activity though it is certainly true that final remodelling of bone with re arrangement of the internal bony architecture is a response to functional weightbearing or compression forces

METHOD

After resecting the articular surfaces of the joint the humerus is fixed to the scapula by means of a screw We prefer a wingscrew (Fig 1) of such length that no part of the screwthread grips the humerus The position of the arm varies from 20 to 40 degrees forward elevation with 60 to 80 degrees abduction (the angle between the humerus and the axillary border of the scapula) The exact position is decided before hand in accordance with the patient s work when making the abduction frame (of Kramer wire) A broad elastic band is attached close to the axillary part of it of such length that when the frame is applied after operation it can be brought out through a window on the elbow joint and looped up to a hook in the plaster bandage used to fix the wire frame in position (Fig 2 and Fig 3) The tension of the elastic must be regulated so that it excercises *steady* pressure of the humerus against the scapula the intention being not to compress forcibly but to ensure close and lasting contact between the resected surfaces

The splint is maintained for seven to eight weeks during which time the tension should be checked frequently The plaster may then be removed from the forearm and the patient starts active and passive movements of the elbow the elastic being temporarily rehooked (Fig 4) Three months after operation the splint is exchanged for a lighter and simpler abduction frame without elastic compression and after a further two months all splints are removed

COMMENT AND DISCUSSION

Different kinds of mechanical appliances have been tried in arthrodesing the shoulder to ensure bony contact at the resected surfaces Their use means however firstly an additional stage in the operation and may secondly give rise to technical difficulties The elastic band

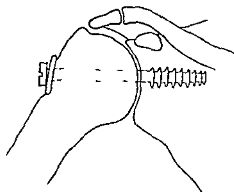


Fig 1
The figure illustrates which kind of screw we prefer and how to place it



Fig 2
The abduction frame is made of Kramer s wires and a broad elastic hand is attached to the upper part of it



Fig 3
The hole made in the plaster corresponds with the width of the elastic band which is drawn round the elbow and fastened to a hook (a) in the plaster

compression is *exteremly* simple It does not affect the operation and can be executed by anyone

It may be objected that the above mentioned screw fixation makes additional elastic compression redundant In reply it should be noted that

1) The bone may be so porotic (Fig 5 a—tuberculosis poliomyelitis) that it is impossible to insert a screw or to get a hold in the cortical bone of humerus for threads or pins In such instances elastic compression is in our hands the only sure means we have of creating contact at the place of resection
2) Even if one obtains solid fixation with a screw thereby possibly preventing movements during the first weeks the screw will gradually loosen This together with the resorbtion of bone at the resected



Fig 4
The plaster is removed from the forearm and the patient is starting active movements of the elbow the elastic being temporarily rehooked The splint is attached to a bandage around the sound (right) houlder

surfaces makes close contact desirable for the whole duration of the osteogenetic process

After the introduction of this kind of compression arthrodesis of the shoulder our clinical experience shows that patients become free of pain considerably *more quickly than before* Once the immediate post operative reaction has subsided the patient usually appears completely free of pain *which is the best clinical indication of sufficient immobili sation* and intimate contact at the resection site

Some orthopaedic surgeons maintain that the muscle tone near a joint is sufficient to keep up the contact between the resected surfaces during the osteogenesis It is not necessary to have operated on many patients with poliomyelitis or tuberculosis of the shoulder before one realises that the muscle tone offers no contribution to the desirable compression factor (see Fig 5 a and Fig 7 b) In such cases the elastic band compression in our opinion is the "method of choice

CLINICAL MATERIAL AND FOLLOW UP

From 1952 till 1955 inclusive we have used the described method in arthrodesis of the shoulder on a total of 34 patients Table 1 shows the different conditions for which arthrodesis was undertaken It must be noted that many of the cases of tuberculosis were in an *active* stage at the time of operation (We were not nervous about operating directly on tuberculous joints even *before* the use of streptomycin)

After discharge from the hospital the patients have been re examined as out patients at intervals of 3 to 4 months the intervals gradually



Fig 5

a. – X ray showing a wide spread tuberculous destruction of the left shoulder in a 35 year old man

b – The same patient as in Fig 5 a 2 months after arthrodesis has been performed (with elastic band compression)

c – The same patient as in Fig 5 a 5 months after the arthrodesis

d – The same patient as in Fig 5 a 7 years after the arthrodesis

becoming longer up to 1 year They were all recalled again for the purpose of this investigation The follow up study (clinical examination and X rays) took place during October and November 1959 The observation period varies from 7 years to 34 months on an average 4¾ years

TABLE 1

The Condition for which Arthrodesis of the Shoulder was undertaken and the Results

Nature of disease	Number of cases	Age (average)	Clinical union and probable bony union on X-ray within	Solid fusion on X-ray (cross in trabeculae) within
Tuberculosis	23	35	8 weeks	5 months
Poliomyelitis	6	27	8 weeks	4 months
Arthrosis capitis humeri	2	51	10 weeks	7 months
Necrosis capitis humeri	1	60	8 weeks	5 months
Luxatio articul humero scapular	1	35	7 weeks	4 months
Chondromatosis art humero scapularis	1	49	No clinical and radiological union within 1 year	

RESULTS OF TREATMENT

The results must be regarded as very satisfactory (Table 1) In every case exept one we obtained definite bone ankylosis (clinically and radio logically) The term clinical union has different meanings to different authors and our interpretation therefore requires definition and ex planation If it is impossible to move the humerus passively (the inferior angle of the scapula being held in a tight grip) without the slightest movement of the scapula and this is completely painless to the patient we consider the shoulder to be fused The shortest time for radiological appearance of union is difficult to assess Table 1 indicates the time for *probable* bony union and the time for solid fusion with trabecula cross ing the junction line It covers the period during which the patient had routine check ups It is possible that more frequent check ups would reveal that radiological ankylosis occurs earlier This however will always be a point of discussion and bony union on X ray may be very difficult to asses before the crossing trabulae appear The inserted screw is a good help in judging this because the smallest movement at the point of resection will result in greater or lesser transparency of bony structure around the end and/or the head of the screw

It should be mentioned that the series includes 4 cases of re resection All were previously resected with attempted arthrodesis but without success Further resection with elastic compression was successful This does not prove the value of the method but indicates it



a b

Fig 6

a – Tuberculos s of the left shoulder (33 year female)
b – The same patient as in Fig 6 a X ray shows bony union 3 months after re section and arthrodesis

Fig 7

a Paralytic shoulder girdle afte poliomyelitis (18 year male) X ray shows the position of the arm whe raised passively

b – The same patient as in Fig 7 a The arm hangs down by its w we ght (held a little away from th body)

c – The same patient as in Fig 7 a 3 months after arthrodesis of th shoulder The resection line can no be seen

ILLUSTRATIVE CASE REPORTS

A few cases (choosen as prototypes) will illustrate the usefulness and help we have derived from the described method

Case 1 Male (A S) 35 years old Complained of pain in the left shoulder for 25 years worse in recent months Admitted to the Hospital 20/6–52 X ray films showed wide spread destruction of the shoulder (Fig 5 a) After preoperative exercises of the muscles of the scapula forearm and the hand resection and arthrodesis were performed 1?/8 52 We have to remove large portions of both humerus and scapula because of tuberculous destruction (all bone tissue between the arrows on Fig 5 a had to be resected) The humerus was so porotic that it was impossible to obtain a grip for a screw or a wire 2 months after the operation there was solid union clinically X rays showed *probable* bony union (Fig 5 b) and after further 3 months we can see the site of resection (Fig 5 c) but with incipient crossing trabeculae X rays on follow up 7/10–59 showed nearly the same picture (Fig 5 d) as Fig 5 c

Clinically solid union free of pain fully at work In this case there is no doubt that the rapid union obtained must be due to the elastic compression

Case 2 Female (S S) 33 years old Complaining of pain in the left shoulder for 10 years becoming gradually worse Admission to the Hospital 31/8–53 with tuberculous destruction of the shoulder (Fig 6 a) Resection and arthrodesis 14/9–53 X rays 3 *months afterwards* (Fig 6 b) showed bony union conforming the satisfactory result of the clin cal examination The line of resection cannot be seen The figure illustrates the kind of screw we prefer to use and how to insert it Follow up 18/10–59 Union cl nically X rays showed the same picture as in Fig 6 b

Case 3 Male (H H) 18 years old Poliomyelitis 5 years old with subsequent paralysis (palsy) of the muscles of the right upper arm and shoulder girdle except those f the scapula Admitted to the Hospital 12/2 54 Fig 7 a shows X ray taken when the arm was raised passively and Fig 7 b when it hung down by its own weight but held a little away from the body Here there is no active muscle tone which could serve as physiological compression postoperatively Arthrodesis performed 25/? 54 Fig 7 c shows the case *3 months later* Bony union with crossing trabeculae It is impossible to rediscover the joint surfaces Clinically complete union Follow up 28/10–59 the same picture as before clinically and on X rays

SUMMARY

The author touches briefly on the question of whether compression should or should not be applied in connection with arthrodesis and concludes that *careful* compression is an advantage He then describes a method of elastic band-compression which has been in use at Martina Hansen s Hospital in arthrodesis of the shoulder since 1952 a broad elastic band is fastened to the abduction frame on which the arm will

be immobilised postoperatively The band is attached so as to admit of a cautious pull towards the resection surfaces which are fixed together by a large screw The advantage of this arrangement is mentioned and discussed in comparison with other methods

The results of 34 arthrodeses of the shoulder by the described method bony union demonstrable in 33 cases fibrous union in one

Lastly brief case and X ray illustrations are presented

RESUME

L auteur mentionne brievement la question de savoir s il convient de s efforcer ou non d etablir une compression en relation avec les arthrodeses et conclut qu une compression *moderee* presente sans aucun doute certains avantages

Il decrit ensuite une methode qui utilise le principe de la compression d une maniere tres simple Elle a ete appliques a l hopital Martina Hansen depuis 1952 dans les arthrodeses de l epaule et consiste a fixer une large bande élastique a l attelle d abduction qui est utilisee pour la fixation de la partie superieure du bras post operatoirement et qui est fixée au tronc par un bandage platré La bande elastique est placee sous le coude et autour du coude – a travers un trou pratique dans le platre – et est fixee à un crochet qui se trouve a l extérieur du bandage immobilisant a proximite de l epaule La bande exerce par la une pression continue qui peut etre réglee sur le coude en direction de la partie superieure du bras vers l endroit de l arthrodese D ailleurs on utilise si possible une vis a ailettes pour la fixation primaire des surfaces osseuses qui restent

Il est discute de l avantage de cette méthode par comparaison avec d autres methodes de compression plus compliquee

Le resultat de cette compression élastique appliquee dans 34 cas d arthrodese de l articulation de l epaule a ete une ankylose osseuse dans 33 cas une ankylose fibreuse dans 1 cas

Enfin il est redu compte de quelques cas a titre d exemples accompagnes des radiographies

ZUSAMMENFASSUNG

Der Verfasser bespricht in Kurze ob eine Kompression in Verbindung mit einer Arthrodese erstrebenswert ist oder nicht und er kommt zu der Schlussfolgerung dass eine mässige Kompression unzweifelhaft gewisse Vorteile bietet

Weiterhin beschreibt er eine Methode die das Kompressionsprinzip in einfacher Weise ausnutzt Sie wurde am Martina Hansen Hospital seit 1952 bei Arthrodesen im Schultergelenk verwendet und besteht darin dass man eine breite elastische Binde an der Abduktionsschiene die man postoperativ zur Ruhigstellung des Oberarmes verwendet befestigt und weiterhin mittels einer Gipsbinde am Brustkorb festmacht Die elastiche Binde wird dann nach abwärts unter und um den Ellbogen (durch ein Loch im Gips) gefuhrt und an einem Haken aussen an dem ruhigstellenden Verband in der Nahe der Schultergegend befestigt Dadurch ubt die Binde einen gleichmassigen Druck in der Richtung des Oberarmes gegen die Stelle der Arthrodese aus der reguliert werden kann Im ubrigen verwendet man moglichst eine Flügelschraube zur primaren Ruhigstellung der resezierten Knochenflachen

Die Vorteile der Methode werden im Vergleich zu anderen komplizierteren Kompressionsmethoden besprochen

Ergebnis dieser elastichen Kompression angewendet bei 34 Arthrodesen im Schultergelenk knocherne Ankylose in 33 Fallen fibrose Ankylose in 1 Fall

Zum Schluss berichten man über einige Falle als Beispiele und weist die Rontgenbilder vor

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HEAD OF THE SURGICAL DEPARTMENT DR HALVARD SKEIE M.D
(FROM 1956) DR KAARE BENDIXEN M D
HEAD OF THE RADIOLOGICAL DEPARTMENT DR JOHS SLØRDAHL M D

EARLY DIAGNOSIS AND TREATMENT OF HIP JOINT DYSPLASIA

By

INGULF UTHEIM MEDBO

Congenital dislocation of the hips has probably been known for thousands of years Treatment has varied through history Both the treatment and the results of the treatment have been made the subject of intense interest in medical literature

In more recent decades it has become more and more obvious that the earlier the treatment begins the greater is the chance of achieving a good result It is generally accepted in the literature that the best results are obtained when treatment is started in the neonatal stage These observations form the background to the study of which an account is given in these pages

During the years 1950 to 1954 a relatively large number of patients were admitted to Fylkessjukehuset in Alesund for treatment of congenital hip joint dysplasia (h d) at the age of 1–3 years In the late fall of 1954 therefore it was decided to begin routine examination of all newborn children in the hospital s maternity department and from the 1st of January 1955 such an examination was consistently carried out

SCHEME OF INVESTIGATION

a Clinical examination

Examination of the hips was made part of the routine examination of all babies in the maternity ward Doctors on duty examined the hips of all children when they were 3–5 days old When somewhat later a pediatrician was added to the hospital staff this series of examinations was so well organised that no reason could be found for changing the routine

The clinical signs which were looked for were as follows

1. Ortolani s sign (snapping sign)
2. Instability of the hips (telescoping sign)
3. Limited abduction of the hips
4. Shortening of the femora
5. Crepitation sound, feeling in the hip joints on passive abduction

This last sign has scarcely any pathognomic significance as e g 1 and 2 but in certain cases this was the only pathological finding in hips which were undoubtedly dysplastic We followed up all babies with this sign In the great majority the hips developed in a completely normal way without any treatment No exact explanation of the finding can be given It may possibly be due to a certain looseness of the connective tissue in newborns who are still under the influence of the mother s hormones In the few cases in which it indicated the presence of a dysplasia the sign was regarded as an abortive Ortolani s sign

b Radiological examination

In the first year of this series X rays were taken of the hip joints in all babies who were suspected of hip joint dysplasia following clinical examination X ray examination was made the day after the clinical examination i e when the baby was 4–6 days old

In the following two years X ray examination was only carried out on newborns when convincingly positive symptoms were present on clinical examination In all cases however X ray examination was undertaken at the age of 3–4 months

The findings at this time decided the need for future follow up

We sought to evaluate by means of X ray pictures taken of newborns the following radiological details

1. The acetabular index
2. Lateral position of the di phy [illegible] in relation t the acetabulum
3. Shenton s line
4. The development f the anter r and the p sterior acetal ular rim
5. The upper lateral border f the [illegible] et ful m
6. The upper end of th di physis in relati n t the [illegible] turat r line

c Other data on mother and child

In connection with the first clinical examination certain data was collected on mother and child so as to determine further factors of etiologic importance

The following were noted the child s sex weight at birth length

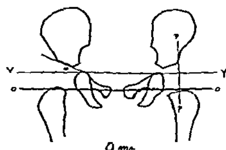


Fig 1
Normal pelvis with auxiliary lines
YY = Y line OO = obturator line
PP = line of gravity through the upper lateral border of the acetabulum
a = the acetabular index

position in womb and order of precedence in the family In addition the mother s age was recorded and information was sought as to any history of h d in the family

TREATMENT

The principle determining treatment was that this should be initiated as far as possible immediately the diagnosis was made i e in the first week of life

This was observed with 41 of the 50 babies

In 7 of the remaining cases treatment was begun along with the first check up i e at the age of 3–4 months The cause of this was partly administrative mistakes partly the fact that the diagnosis could only be determined with certainty at this period

In the last two cases treatment was not started until the age of 7 and 10 months for the last mentioned reason One of these cases will be discussed later (case no 134 Fig 7)

In the newborns difficulties in reducing the dislocation was never encountered Frejka s cushion splint was used for immobilisation See Fig 2

For practical reasons the actual cushion in this splint was encased in waterproof material Thus the individual patient s need for cushions was reduced to 2-3 cushions The cushion has to be hard to prevent it from being squeezed from one side to the other

On discharge from hospital each mother received instruction in the use of the splint and got one complete splint as a gift from the hospital so that one should be certain that the remaining splints had the correct dimensions In our very first case forming one of the cases in which the treatment is stated to have begun only at the age of 3–4 months an attempt was made to obtain the effect of the Frejka splint by an apparently more easy way

On discharge the mother was requested to use several diapers at a

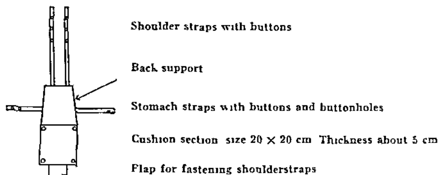


Fig 2
Frejka s cushion splint size 1 10
The buttons in the corners of the cushion section are connected with elastic around *the child s thighs*

time thereby achieving the intended abduction position of the hips This method of treatment proved to be completely useless and at the first follow up it was replaced by the customary cushion splint delivered and demonstrated for the mother as described above

Any attempts to replace the original Frejka splint in this way is inadvisable Regarding the relationship of the patients to the cushion splint and perhaps especially the mother s attitude to this the following questions were put as routine to the mother at each later check up

1 Do you think that the baby suffers any discomfort from the splint?
2 Does it seem to you yourself that it is troublesome to put on the splint?
3 Have you any objections to the splint?

The first question was consistently answered No

In reply to the second question a few found that it seemed difficult to put the splint on to begin with Afterwards all went smoothly and the common answer was that it was not more difficult to put the splint on than to put on ordinary diapers

In answer to the third question a few brought forward the objection that they did not care for the splint from purely aesthetic reasons They were reluctant to show the baby to the family and friends because it was so difficult to dress up the child in the way that mothers appreciate The great majority had however no objection to the cushion splint

In a few individual cases where at the check up 3 months later no satisfactory reduction had been obtained the cushion splint was replaced by a plaster cast This enclosed the pelvis and both lower extremities to the knee The plaster kept the lower extremities fixed at

about 90° flexion and 70° abduction of the hip joints. Corresponding procedures were employed in individual cases where treatment was initiated at the age of 3 months or later when abduction was hindered to such an extent that the dislocation could not be reduced without recourse to anesthesia. In such cases also immobilisation in a plaster cast was adopted for 3–4 weeks. Afterwards the plaster was removed and replaced by cushion splint. This procedure proved very effective and was clearly much less troublesome to the patient and mother than a lengthy immobilisation in plaster.

Complete immobilisation in the cushion splint was pursued until a clinically stable hip joint was achieved. This was very often the case as early as the first check up (age about 3 months). In doubtful cases, especially when the clinical and radiological findings did not correspond, the immobilisation was maintained longer. In the last follow up period it was recommended that the cushion should only be used in the normal sleeping hours of the baby so that she/he was free to move the lower extremities for some hours every day.

PATIENT MATERIAL

My series comprises all children born in the department during the years 1955–1956–1957. Table 1 records the total of these patients.

As the table shows, the examination comprises 3242 children.

At the clinical examination the findings were negative in 3099 children, but in the remaining 143 findings were made which were regarded primarily as pathological. The latter were all examined once or several times both clinically and radiologically. On the basis of the findings which were made at the first examination or later, 50 children were selected in whom the author believed that clear pathological changes were present in the hips, either in the form of hip joint dislocation or subluxation or a type of h. d. This gives a morbidity of about 1.5 %.

TABLE 1
Survey of children examined

Year	No. of births with children living	Twin births amongst these	Twins living	No. of children examined
1955	1035	8	16	1043
1956	1115	14	28	1129
1957	1054	19	35	1070
Total number of children examined				3242

This figure may seen strikingly high and manifests a morbidity in this series which surpasses by far what is commonly thought to occur with h d in Norway The author has observed this point and has repeatedly gone through the series with the aim of reducing the number of probable pathological hips This attempt was not successful however and it was thought that the series should be reported so that it could speak for itself

It was mentioned above that 143 babies were originally selected who were thought to show pathological changes in the hips on clinical examination immediately after birth Of these there were only 50 therefore in which the primary diagnosis was thought to be correct The other 93 babies offered at birth only sensations of crepitation in the hip joints on abduction Radiological confirmation of the disease could not be obtained by pictures taken when the baby was 3–4 days old At the beginning of the investigation treatment was started in a number of these patients After more experience was gained this treatment was found unnecessary so that the great majority were not treated

In spite of this the diagnosis h d could never be confirmed at later clinical and X ray examination and one must therefore assume that the crepitating sensation on abduction of the hips in newborns may occur without any pathological significance In a few cases of these babies with crepitation as the sole clinical symptom it has been possible however to demonstrate undoubted h d at further check ups (3 months old and later) Attention is therefore drawn to this symptom which in the author s opinion may represent an abortive Ortolani s symptom

RESULTS OF EXAMINATION AT THE NEW BORN STAGE

a Clinical examination

On examination just after birth the clinical symptoms of the 50 children were as follows

Ortolani s sign bilaterally	8
Ortolani s sign right hip	16
Ortolani s sign left hip	8
Instability bilaterally	1
Instability right hip	7
Instability left hip	1
Doubtful instability in one or both hip	4
Crepitation in one or both hips on passive abduction	4
No clinical findings	1
	50

Ortolani s sign is only stated positive when one could dislocate and reduce the hip concerned with certainty

Moreover it is felt that the instability sign most probably represents a pathological hip This is stated positive when one could with certainty press the femur so far in the dorsal direction that one would not consider it reasonable that this movement should proceed within a normal joint

In the four patients where instability is recorded as doubtful mobility was so small that it was possibly due to general relaxation of the joint in the postnatal period

Greater doubt may arise concerning the group with crepitation in one or both hips As stated above the author believes that this symptom can be regarded as an abortive Ortolani s sign even if it can be provoked in a number of babies in whom at later examinations h d can be excluded

A good illustration is obtained of a case where such a crepitation on passive abduction movement of the hip joints was the only finding on examination in the newborn stage on studying X rays of case 36 Fig 13 Unfortunately the first X ray examination was undertaken at the age of 3½ months

The last case in which nothing pathological was noticed on examination immediately after birth was discovered when the baby was [illegible] months old see case no 134 Fig 7

b Radiological examination

The radiological findings in newborns were as follows

Certain dislocation or subluxation	16
Probable dysplasia	10
Probable negative finding on X ray examination	19
X ray exam not carried out in newborn stage	5
	50

There are scarcely any reasons for general remarks on the above apart from the fact that the X ray examination produces far fewer positive findings than the clinical examination What is most interesting in this connection is whether there is any correspondence between the clinical and the radiological findings

If one reviews the eight cases with clinical findings

Ortolani + Inlat , the radiological findings are as follows

Bilateral dislocation or subluxation	5
Bilateral dysplasia	1
Unilateral dysplasia	1
Negative findings	1
	8

The 24 cases with clinical findings Ortolani positive in right or left hip show the following X ray findings

Dislocation or subluxation same side	11
Dislocation or subluxation opposite side	2
Dysplasia same side or both	5
Negative findings ..	6
	24

A corresponding summary can be made of the other clinical groups with an increasing failure in the radiological diagnosis

With regard to the 32 cases with the clinical diagnosis Ortolani s sign positive all the cases with radiological findings dislocation or sub luxation coincide within this group On the other hand however con vincingly positive radiological findings were only found in 16 of 32 babies who were declared to have completely reliable positive findings on clinical examination and in fully 7 cases the X ray diagnosis was completely negative in a very critical evaluation in spite of the positive clinical findings

The question may then be put is not amongst these 7 the clinical diagnosis faulty and the radiological one correct? With this in mind I studied the results of the first follow up examination of these 7 child ren This took place when the child was 3–4 months old

The findings on clinical and radiological examination were these

Clin ex	Neg findings	
Rad ex	No or doubtful positive findings	2 cases
Clin ex	Neg findings	
Rad ex	Delayed development of epiphysis	2 cases
Clin ex	Neg findings	
Rad ex	Undoubted dysplasia findings	2 cases
Clin ex	Not performed	
Rad. ex	Neg findings	1 case
		7 cases

In order to evaluate the above one must bear in mind that all these babies commenced treatment immediately after birth In the author s experience it rarely or never happens that on examination at 3 months

of age clinical symptoms will be found positive and it is rare that there will be definite pathological findings on X ray examination In spite of this however pathological findings were made at the first follow up examination in 4 out of 7 these findings were due in all probability to a hip joint dysplasia or—dislocation This makes it most likely that the clinical diagnosis at the neonatal examination was correct and that the X ray diagnosis was at fault

The conclusions to be drawn from this rather detailed evaluation of the symptoms found on clinical and radiological examination of new borns are that the radiological examination is much inferior to the clinical at this age In addition I believe to have demonstrated that a positive Ortolani s sign at birth is such a certain symptom of h d that it will be a failure of technique if it is not heeded and treatment does not begin with the newborn baby

c Other clinical data from the newborn stage

As stated above the series comprises 3242 children Based on clinical and radiological examination of the hip joints of these children it is considered that hip joint dysplasia is present in 50 children

Below is given more clinical data on these 50

TABLE 2
Sex distribution

Sex	No	No given in
Girls	43	86
Boys	7	14

This distribution between the sexes corresponds well with the figures found elsewhere in the literature

The information collected about the position of the foetus determined in relation to the birth showed nothing unexpected On the whole the distribution was normal with a certain emphasis on the breech position since 6 children or 12 % were born in this position

Nor was anything unusual found in respect to which order in the family these children came

As far as the mothers were concerned the mother s age was noted when the child was born This was on average 29 9 years In a control series of 93 mothers with normal children born in the same period the average age was 29 3 years

Finally information was requested about other known cases of h d

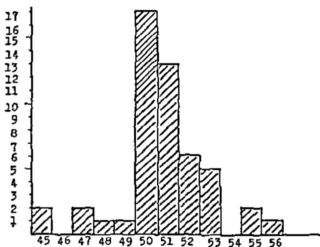


Fig 3

Length at birth

Abscissa Length at birth given in centimetres

Ordinate Number of children

Each column represents the children whose length at birth lies within the same centimetre If this graph of length at birth is compared with the corresponding graph in Sundal s normal series from Bergen in 1956 the same pattern is found on the whole If the average length of the 50 children is calculated this is 50 74 cms Sundal states that the average length of boys is 50 9 cms and of girls 50 ? cms A series composed of 14 % boys and 86 % girls will then achieve an average length of approx 50 3 cms i e somewhat less than in my series

in the family Here positive information was received in 17 of the 50 children i e 34 %

RESULTS OF TREATMENT

In the great majority of children the treatment was commenced a few days after birth As explained above such early treatment was started in 41 out of the 50 children In the remainder the treatment commenced later but in all cases before the child had begun to stand or walk

In order to assess the results of treatment it was decided to divide the children into two groups Group I comprises the 41 children in whom the treatment was started in the newborn stage Group II comprises the remaining 9 children

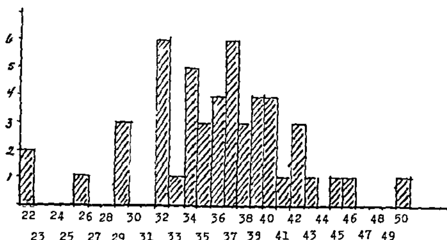


Fig 4
Weight at birth
Abscissa Weight at birth stated in 100 grams
Ordinate Number of children

Each column represents the children whose weight at birth lies within the same 100 grams The pattern in this graph of the weight at birth of the 50 children also corresponds with the graph in Sundal s normal series The average weight at birth is calculated at 3 608 gr Sundal states the normal weight of boys to be 3 500 gr and of girls to be 3 400 gr A group composed of 14 % boys and 86 % girls will then have an average weight of 3 414 gr i e somewhat less than in my series

GROUP I

The first control examination within the group took place in 39 cases when the child was between 3 and 4 months old In the last two cases the age was respectively 5 and 6 months The results of the clinical examination at this point was as follows

Negative findings	37 patients
Positive findings	4 patients
	41 patients

Positive findings in this connection mean that the hip could be dislocated and reduced with certainty or that shortening of the extremities could be demonstrated with limited abduction and positive telescoping sign In the X ray examination which took place the same day the following was found

Negative findings	23
Dysplasia signs in one or both hips	11
Dislocation or subluxation in one or both hips	4
No satisfactory X ray exam	3
	41

There was very good correspondence here between clinical and X ray examination since all in the group negative findings in the X ray examination turned up again in the same group in the clinical examination

All the dislocation findings in the clinical examination could as was to be expected be confirmed at the X ray examination

The X ray symptoms which were given importance in referring a case to the radiological dysplasia group were as follows

a Increased relative acetabular index	6
b Delayed development of epiphysis	3
c Poor development of the anterior and posterior lips of the acetabulum and poorly marked upper lateral border of the acetabulum	11

Cf a This symptom is relatively easy to evaluate and is only noted positive when there is an obvious increase of the angle of incline on one side in relation to the other

Cf b This symptom is also easy to assess One cannot however expect to find it positive in all cases where the control is undertaken at the age 3–4 months since the epiphysis normally does not become radiologically visible until the age 3–6 months

Cf c This X ray symptom may be the subject of considerable subjective assessment but is on the other hand present in all babies In 6 out of 11 it is however supplemented by one of the above more objective symptoms so that one may draw the conclusion that the subjective assessment of the acetabulum is probably not too fortuitous

If the radiological findings in this group are compared with the clinical findings of Ortolani s sign at birth the following is found

Of the 32 babies who had positive Ortolani s sign at birth 30 appear in group 1 In 2 of these the X rays at the first check up were of such quality that no X ray diagnosis may be ventured

In the remaining 28 the X ray findings are negative in 15 (over 0 %) 4 have radiological subluxation and 9 have radiological dysplasia No one has now a complete dislocation From this it can be concluded that Frejka s cushion splint is very effective and that it is a fundamental advantage to begin treatment at such an early stage

Final results of treatment

In assessing the final result of treatment certain difficulties of evaluation are encountered As stated the children were followed up until the examiner at the clinical and radiological check up was of the opinion that the hips were normal and showed no signs of becoming worse after the splint treatment was ended i e the last check up occurred at least 3 months after the continuous treatment was finished The end result of the examined babies will be assessed according to this principle at most varying ages and these lie between 6 and 33 months

In 26 children the age was from	9-15 months
In 9 children less than	9 months
In 5 children more than	15 months

One child did not return for check up owing to geographical reasons
Total 41 children

A *Clinical examination*

No signs of h d were found in any of the 40 children In 19 cases the child was 12 months old on check up and all these could walk or stand with or without support In these cases all had negative Trendelenburg sign as far as could be demonstrated

It may then be maintained that from a clinical standpoint all the children had normal hips

B *Radiological examination*

This appears more problematic both because the end stage is recorded at ages varying between ½ and almost 3 years and because there is no definite standard for the normal hip in this age group The results of X ray examination were judged according to two different principles

First a general picture was formed of the hip joint by taking into consideration the mutual development of the osseous parts of the caput and acetabulum and the adjustment of the caput to the acetabulum

From this point of view an end result was found in 39 of these 40 children which was quite satisfactory The caput and acetabulum had even contours the acetabulum s roof had a suitable angle the anterior and posterior lips were well developed and closed laterally Moreover the caput seemed to be well centred in its joint cavity

A hip joint of normal appearance may thus be said to be present in 39 out of 40 cases In the last case the caput is placed so far laterally and the acetabular contours are so blurred and uneven that an h d is probably still present or possibly a slight subluxation

This method of assessment must undoubtedly be rather subjectively influenced since it depends on the general judgement of the examiner

Secondly these 80 hip joints were assessed strictly geometrically by drawing up 2 of the previously mentioned auxiliary lines Even at this point one comes across the first difficulty since the Y line judging from the literature is drawn rather differently by different authors

It was decided to draw the line as described by *Wiberg* He draws it as a tangent to the upper contour of the os pubis Others draw it rather differently but in all cases it is situated further cranially than that described by *Wiberg*

The second auxiliary line called the P line is drawn through the lateral osseous border of the acetabulum and vertical to the Y line Since the above border is often slightly rounded a slight difficulty is encountered in deciding the localisation of the line and the judgement of the examiner again comes into the picture

After these lines are drawn all hips are said to be normal where the caput in its entirety lies in the lower medial quadrant

In those cases where 0–2 mm of the caput lies above the Y line or laterally of the P line the hips are called normal? This method of assessment was chosen because there will always be a certain doubt about the exact localisation of the auxiliary lines described In no case does the caput lie more than 2 mm above the Y line

In those cases where 3–5 mm of the caput project laterally of the vertical line the designation dysplastic? is used

In those cases where the divergence is greater than that stated above the hip joint is called dysplastic

The results of this strict assessment of the babies are as follows

"Normal" hips	22 babies
"Normal?" hips	12 babies
"Dysplastic?" hips	5 babies
Dysplastic" hips	1 baby
	40 babies

Much doubt was felt whether it was right to describe pathological conditions in a hip joint so systematically Firstly as already mentioned some doubt was felt where the auxiliary lines were to be drawn Secondly the question occurs whether here as elsewhere in man s anatomy one *must not make allowances for minor individual variations* Thirdly it was not possible to find anywhere in the literature an account of what should be regarded as the norm for the hip joint in children of

this age group namely 1–3 years Studies were found which stated the normal outer limits for hip joints in adults and children down to 6 years but not for the younger children

When the investigation was being pursued *Andren & von Rosen*s examination technique was not published and therefore this could not be evaluated

If the end results of the treatment of these 40 children according to the three procedures described are studied the following emerges

Clinical exam	Normal hips	40 children
General radiological assessment	Normal hips	39 children
	Dysplastic hips	1 child
Radiological assessment in relation to the quadrant division of the hip joint	Normal hips	34 children
	Possible dysplastic hips	*5 children*
	Certain dysplastic hips	1 child

On the basis of the above it is believed that the treatment in 39 of the 40 children has led to the healing of the existing defect in the hip joints while in one case complete healing has not yet been achieved

This last case represents undoubtedly an error in treatment on the part of the examiner in that the whole purpose of the investigation originally was aimed at demonstrating how valuable Frejka s cushion splint was For this reason splint treatment alone was continued until the child was 14 months old At this time certain dislocation existed in the right hip A change was made to plaster and at the next check up the right hip was reduced very nicely but as stated the caput is still placed rather far laterally nor can one say really that any certain subluxation is present A more elastic attitude by the author would undoubtedly have produced a better result In later cases of the series the experience acquired from this lesson was applied If complete stability was not achieved in the hip during the course of a control period of 3 months the cushion splint was replaced by plaster administered if necessary under anesthesia After 3 weeks the plaster was removed and the Frejka treatment was again adopted In such cases no sign of recurrence was ever seen

GROUP II

The group comprises 9 children

In 7 of these children treatment was begun at the age 3–4 months In the last two the age was respectively 7 and 10 months

A *Clinical examination*

The last clinical examination of these took place between 1 and 1½ years of age. In no case could signs be demonstrated of pathological conditions in the hips. All had started to put weight on their lower extremities in the erect position. In those cases where it was technically possible Trendelenburg's test was carried out with negative results. The results of the clinical examination were thus negative in 100 %.

B *Radiological examination*

The last X-ray examination was carried out at the same time as the clinical one. On assessing this uncertainty arises again as described before since it is not definitely known which radiological standards must be applied to the normal hip in the age group involved here.

The general impression of the examiner in assessing the present X-rays is that in all cases the hip joints concerned under routine conditions would be regarded as normal. The acetabulum is well developed with a centrally placed epiphysis of normal shape.

If the existing pictures from the last check-up are studied strictly geometrically in this group and if the caput's position is assessed in relation to the previously described auxiliary lines in the same way as in Group I, the following end results are obtained:

Normal hips	2 children
"Normal?" hips	2 children
Dysplastic? hips	5 children

On comparing the clinical and radiological findings this group is believed to have achieved probable normal hips in all cases, i.e. 100 %.

If the strictly geometrical assessment of the end result has any value in comparison between these two groups, it appears that even a postponement of treatment from the birth of the child until he (she) is 3–4 months old is unfavourable.

COMBINED ASSESSMENT OF GROUP I AND II AT THE CONCLUSION OF TREATMENT

It is the author's opinion that the two groups of results treated here are so small and that the time of initial treatment varies so little that no great mistake will be made if the two groups are combined.

The following total results are given for the 49 children who underwent full follow-ups:

Clinical examination	Normal hips	49 children
General radiological assessment	Normal hips	48 children
	Dysplastic hips	1 child
Radiological assessment in relation to the quadrant division of the hip joint	"Normal" hips	24 children
	Normal?	14 children
	Dysplastic?" hips	10 children
	Dysplastic hips	1 child

Even after the strictest assessment therefore 38 children or 77 5 % emerge from their congenital hip joint dysplasia with normal hip joints

In 10 children or 20 5 % the clinical examination shows a completely normal hip joint while a strict radiological assessment shows a slightly lateral position of the caput in one or both hip joints although one can not definitely say that h d exists

In one child certain dysplasia is present in the one hip joint while the other lies in the group above

In 1 child an adequate follow up could not be pursued owing to geo graphical conditions

Seen in relation to the percentage of healing obtained in congenital h d when treatment is commenced after the child has started to walk the results are believed to be so favourable that any postponement at all of the treatment after the newborn stage must be regarded as an error of technique

PRESENTATION OF CASES

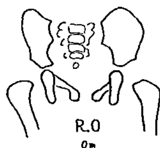
To give the reader a better understanding of the view points main tained by the author some case histories with tracings of X rays are presented There are three cases from each of the groups Normal hips "Normal? hips and Dysplastic? hips

Group Normal hips

Case No 30 R O b 25/9 1955 Fig 5

Family history	No known cases of h d
Clin ex at birth	Ortolani s sign pos right hip Shortening of right femur and assymm skin folds
X ray ex at birth	Probable sublux in right hip
Treatment and course	Commenced immediately after birth with Frejka s cushion splint This was used day and night for 6 months after wards at normal sleeping hours for a further 2 months Walked and stood with support at ca 10 months
Last check up (15 mos)	Clinical ex Completely normal hips

Walks without limp Trendelenburg — bilat
X ray normal hips both caputs in the lower medial quadrant Right caput insignificantly smaller than the left



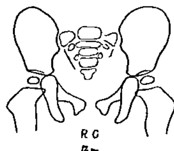
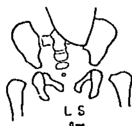


Fig 5



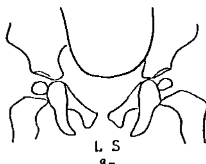


Fig 6

Group Normal hips

Case No 143 L.S b 1?/12 1957 Fig 6

Family histor	No known ca es of h d
Clin ex at birth	Ort lani s sign pos bilat with relati e shortening of the femora
X ray ex at birth	Pr babl dy plasia bilat
Treatment n l cou	Fr jka cushion splint treatment tart l at birth This was used c ntinuousl for 6 month afterwards during leeping hours for a further 3 month N mal develop ment of the hip jo nt
La t ch k up (9 m	Clin ex normal hips
	X ra normal hip joints Caput in lower medial quadrant bilat

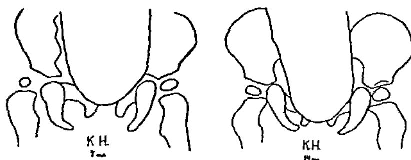


Fig. 7

Group: Normal hips

Case No. 134 K.H. b. 5/9 1957 Fig. 7

Family history	Twin sister with certain clinical and radiological luxation in left hip at birth
Clin. ex. at birth	Neg. findings
X-ray ex. at birth	Not performed

Owing to the examiner's interest in twin cases in this series the patient was called for check up with her sister 7 months old.

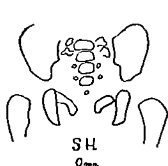
Clin. ex. age 7 months	Limited abduction in right hip, assymm. skin folds and probable shortening of right femur
X-ray ex., age 7 months	Certain dislocation in right hip
Treatment and course	Reduction performed under anesthesia without difficulty. Position maintained in plaster. After 3 weeks plaster cast replaced by *Frejka's cushion splint*. This was used continuously for 3 months, afterwards during sleeping hours for a further 3 months.
Last check up (14 mos.)	Clin. ex.: normal hips. X-ray ex.: both hip joints appear normal but right caput is still a little smaller than the left.

Group: Normal hips

Case No. 43 S.H. b. 12.4.1956 Fig. 8

Family history	3 certain cases of h.d. in the father's family
Clin. ex. at birth	Ortolani's sign pos. right hip
X-ray ex. at birth	Certain lat. position of upper end of femur right sid. with slight uprooting of same and increased acet. incline bilat.
Treatment and course	Frejka cushion splint used from birth. The cushion was used continuously for 6 months. Afterwards treatment was concluded. After only 3 months clin. ex. was negative while there were continued signs of dysplasia in both hips on X-ray ex.—Started to walk without limping at 1 year.

Last check up (96 mos)	Clin ex completely normal hip joints
	X ray ex at first sight the hips appear completel n rmal bilaterally but on both sides the caput projects ab ut mm above the Y line and about 9 mm laterally f the P line



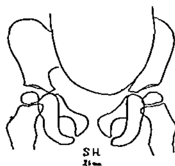


Fig 8



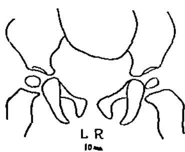


Fig 9

Group "Normal hips

Case No 118 L.R b 8/7 19 7 Fig 9

Famil hi t r	One ca e kn wn in a li t nt relati in the moth r s family
Clin ex at birth	Ort lani s gn p itive bilat Left h p s l e that it did in fact dislocate a soon a the bab wa laid on its back
X ray ex at birth	C nsi leral le in re e in acetal ulum angle of incl ne bilat
Treatment and c urse	Frejka cu hion plint treatment started at birth At th fir t check up certain il l cati n c ntinued to be pre ent in the left hip F s r duction with ut nest sia wa ob taine l R ducti n m intained in pl ter After 3 weeks the

	plaster was replaced with Frejka's splint This was used continuously for 3 months Afterwards again for 3 months with two hours freedom from the splint each day Could stand with support after 10 months
Last check up (10 mos)	Clinical ex normal hips
	X ray ex bilat the caput projects 1 mm above the Y line and on the right side 2 mm outside the P line

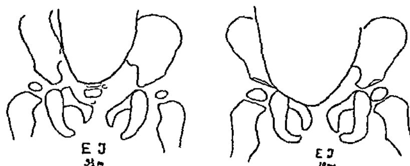


Fig 10

Group "Normal?" hips

Case No 79 EJ b 5/1 1957 Fig 10

Family history	No known cases of h d
Clin ex at birth	Pronounced crepitation and some looseness in left hip joint Ortolani's sign neg No instability
X ray ex at birth	Not performed
Treatment and course	No treatment begun at birth At first check up aged 3½ months limited abd was found in right hip and definite instability in left hip X ray findings Probable subluxation in both hips Reduction was undertaken under anesthesia Stability was easily obtained in the reduced position with Frejka's cushion splint This was used continuously for 3 months then at sleeping hours for a further 3½ months
Last check up (10 mos)	Clinical ex Normal hip joints
	X ray ex On immediate study both hip joints appear normal but the caput projects 2 mm above the Y line bilat and also 2 mm outside the P line

Group "Dysplastic" hips

Case No 115 J T N b 28 5 1957 Fig 11

Family history	Elder sister had certain bilat h d In addition the child is closely related with another child in the series

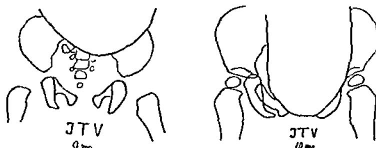


Fig 11

Clin ex at birth	Ortolani s sign pos left hip probably instability in right hip
X ray ex at birth	Upper lateral border of acetabulum is not well marked Rather large angle of incline in left hip Certain signs of dislocation are not present
Treatment and course	Frejka s cushion splint treatment started at birth In first check up after 3 months there was probable instability in both hips on clinical ex X ray showed certain sublux in right hip and somewhat laterally placed caput in left hip It proved that the cushion used was too thin and soft to obtain the desired effect and it was exchanged The new cushion was afterwards used day and night for 6 weeks afterwards omitted 2 hours daily for 6 weeks and then worn only at night for a further 4 months
Last check up (10 mo)	Clin ex normal hips X ra ex left hip completely normal caput on right side projects 3 mm out ide the P line

Group "Dysplastic hips

Case No 10 F E. b 8/4 1955 Fig 12

Family history	No known cases of h d
Clin ex at birth	Ortolani s sign po right hi
X ray ex at b th	Relativel increa ed acetabulum angle f incline on right ide Shenton l n broken bilat lateral po ition of l th fem ral di phy es
Treatment an l c ur e	With clinically certain hip joint l sl cati n n the ight ide a directi e wa given that treatment should b started before li ch rge fr m the maternity war l The directiv wa misinterj rete l however and no tr atment was begun On the first check up c rtain clin dislocation exi ted in the right hip which could be confirmed on X r y ex No succe s was obtained in trying to achieve stable reduction

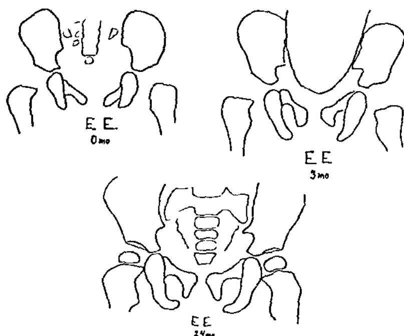


Fig 12

without anesthesia The reduction was maintained in plaster for 3 weeks Then normal Frejka's splint was used continuously to the age of 6 months and then during sleep to 12 months Later checks gave normal findings from the right hip but plain abduction spasm in the left where the epiphysis as well seemed to be more laterally placed than on the right side At 14 months tenotomy of the adductors on the left side was performed Later the course was normal apart from temporary fragmentation of both caputs At 14 months she could stand with support Walked at 16 months

Last check up (24 mos) Clinical ex Neg findings

Walks freely without limp Trendelenburg's sign neg bilat

X ray ex Well developed acetabulums Right epiphysis 1 mm above and 5 mm laterally of the auxiliary lines Left epiphysis projects 1 mm above and 3 mm laterally of the same lines

Group Dysplastic? hips

Case No 36 G F b 5/1 1956 Fig 13

Family history No known cases of h d

Clin ex at birth Slight crepitation on abduction beyond 80 of left hip

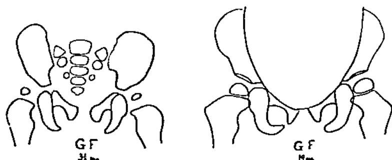


Fig 13

X ray ex at birth	Not performed
Treatment and course	At the first check up age 3½ months certain clin dis location in the right hip confirmed at X ray ex Under anesthesia an easy reduction was carried out The position was maintained in plaster for 4 weeks Then the plaster was replaced by Frejka s splint This was con tinuously used for 3 months Then it was used at sleeping hours for a further 6 months The patient walked without support at the age of 13 months
Last check up (19 mos)	Clin ex walks normally No pathological findings on ex of the hip X ray ex The general impression is that the hip joints are developing normally but the caput projects respec tively 4 and 3 mm above the Y line and 4 and 3 mm later ally of the P line

DISCUSSION

I have presented the results of a consistently pursued investigation into hip joint dysplasia in 3242 children

The 50 children whom I believe had h d at birth were treated and followed up until I considered the hips to be normal

a) *Incidence of h d in the series*

I was very surprised at the high incidence of h d According to other studies from the Scandinavian countries the disease occurs to the order of 0 1 % while in this series it shows a figure of 1 5 % In the Same population in Finnmark a morbidity of 4–5 % was found while the Norwegian population in this province has much the same incidence as elsewhere in the country

According to the research I have made there are at any rate no official statistics on the occurrence of h d The figures presented in the literature are not based then on normal health statistics

From other parts of the world the morbidity incidence is reported as varying quite considerably from place to place The interpretation must be that h d is a disease which in certain geographical areas arises with great frequency while in others it may be very rare I therefore satisfied myself with the explanation that Möre and Romsdal county forms just such a geographical area in which h d has a higher incidence than in Norway as a whole

This theory is supported by the fact that before this investigation was commenced a relatively large number of children were admitted to hospital aged 1–3 years with hip joint dislocation During the years 1950–54 4–7 newly diagnosed cases were admitted each year Even this number is only a third of the incidence shown in the series The explanation of this may be partly that some cases of h d were referred for treatment to a special clinic instead of to the local hospital It is also known from the literature that spontaneous healing of h d does occur It is therefore probable that a number of the cases included in the series would also have achieved healing without treatment The difficulty arises only in that it is not known with certainty who will develop a complete dislocation and who will achieve spontaneous healing

The few cases in which a certain diagnosis of dysplasia was made at birth but in which treatment was mistakenly not commenced do not encourage postponement of treatment in the hope of spontaneous healing

b) *The clinical examination of the hip joint in newborns*

The examination was undertaken with the baby lying supine The hip joints were flexed 90 The examiner placed his thumb over the distal end of the femur and the other fingers over the trochanter region From this initial position the mobility and stability of the hip joints were examined

Based on past experience I believe that Ortolani s sign (snapping sign) and instability (telescoping sign) of the hip joints are convincing symptoms of h d Using the examination technique described these symptoms are relatively easy to observe even for a less skilled examiner

I have never observed limited abduction in the newborn stage except as a link in Ortolani s sign i e when the abduction movement is undertaken in a dislocated hip joint slight resistance to continued abduction

is felt before the caput is tilted into the joint cavity Afterwards abduction may normally be undertaken to about 70 For the symptom to appear alone I assume that a better development of the musculature is required than is found in newborns Later e g at the age of 3 months the abduction blockage will be an important symptom of hip joint dislocation

I have also as a matter of routine taken notice of whether asymmetry was present in the thigh groin or gluteal skin creases

I should like to draw attention to the crepitation noise to be heard on passive abduction of the hip joint In a good number of cases where this was observed at the first examination I checked on the child later without finding signs of pathological development of the joint In some few cases this was the only clinical symptom of h d in the neonatal stage and later examination showed the development of dislocation (see case 36 Fig 13) I would therefore recommend that children who offer this symptom are examined as routine at the age of about 4 months when the epiphysis is visible on the X ray pictures

c) *Hip joint dysplasia in children with negative findings on examination at the newborn stage*

Among the 3242 children who were examined immediately after birth and where the primary result of the examination was Normal hips only 2 cases occurred which were later to be admitted to hospital with hip joint dysplasia In both cases only a moderate degree of dysplasia was present without complete dislocation Both were treated with favourable results

I take this as indicating that clinical examination at the neonatal stage is very reliable

Naturally the objection may be made that perhaps there were other cases of which the examiner was not aware I consider this to be hardly probable because this series of investigations was much publicised by the hospital both amongst the women who were admitted to the maternity ward and amongst the doctors in the district

The fact that taken as a whole overlooked cases do arise is an inspiration towards constant control of the hip joints of infants Carrying out a hip joint examination is so easy and takes so little time that it ought to be included as a routine examination in all infant check ups In particular the examination should apply to girls in families where it is known that h d occurs amongst other members of the family

If this procedure is carried out all cases of hip joint dysplasia should be discovered and treated before the child begins to walk.

d) *Radiological examination of the hip joint*

An attempt was made to take all pictures with the patient lying supine in complete rest with straight lower extremities in the neutral position of rotation and centred towards the symphysis. It will be well known to all who have performed such an examination that it can be difficult, not to say impossible, to persuade a patient in the age group involved here to lie in the correct position during the examination. To avoid overlong exposure I therefore approved in a number of cases X-rays which were obviously not taken in an ideal position. This circumstance should be born in mind when assessing a radiological diagnosis on a purely geometrical basis.

As will appear in the assessment of the end results I found on careful scanning of the X-rays a number of babies who had a very slight lateral dislocation of the caput but at the same time no sign of dysplasia could be detected in the hip joint as a whole, i.e. the caput was normally formed with entirely normal size and contours. The same applies to the acetabulum including the angle of incline. The author cannot declare with certainty today that these hips are normal and will develop normally. It is hardly reasonable to believe that the above mentioned changes are only due to inaccuracies in the radiological technique. A possible explanation is that these cases concern femora with increased anteversion so that X-rays taken with the lower extremities in the correct position of rotation really give a very slight lateral projection of the caput in relation to the acetabulum. I consider it very doubtful that a genuine subluxation is involved. Some children in the series who presented such radiological findings were checked again after getting about without any form of treatment. No increased lateral displacement or signs of uprooting were observed.

It is stated in the literature that the hip joint ends its development in persons in the 17 years age group. I assume than the population group from which this series is derived has stable housing conditions so that it would be possible to follow up these children when they are about 17 years old. Such an investigation is planned. It will possibly give the answer to the question of how much importance a lateral position of the caput may possess in the development of the hip joint.

In this series I have omitted to divide the patients into the usual groups of unilateral and bilateral cases.

In the literature published 20–30 years ago and earlier n t ferentiation was made between uni and bilateral cases On th it was agreed that ⅓ were bilateral and ⅔ were unilateral In publications this distribution was altered in favour of a larger n of bilateral cases I am strongly convinced that one should perh further in this direction and say that congenital hip joint dyspla a systemic disease which affects the development of the hip joint ge ally The degree of dysplasia may vary and this explains why the symp toms found on clinical and radiologacil examination may be localised to one hip only

With a serious degree of dysplasia at birth dislocation may occur in one or both hips

With a slight degree of dysplasia one of two things may happen either the hip joint will develop so that the child begins to stand and walk with normal hip joints or the dysplasia will persist or become worse in the first years so that weight bearing on the lower extremity concerned will pass into a genuine dislocation on one or both sides

If the above view of hip joint dysplasia is correct then the fact that we constantly examine our children in their younger years and that methods of examination constantly grow better will provide in the author s opinion a good explanation of the tendency found in the literature towards a constant increase in the bilateral cases at the ex pense of the unilateral

I have deliberately paid little attention to the importance of the angle of incline of the acetabulum in the radiological assessments

The reason is partly that more recent literature very decidedly asserts that this angle varies so much individually that no clear boundary can be drawn between normal and pathological values Nor in this study was any complete correspondence found between the acetabulum s angle of incline and other symptoms utilised to make the diagnosis h d

It must be said that the angle of incline in the series as a whole is high The average figure for normal angles of incline is put in the litera ture at 28–29 in newborns but with large individual variations which cannot be designated as pathological

In this series X ray pictures of the newborn stage are included of 44 babies in all 88 hip joints 68 of these show an angle of incline of 29 and more An angle of incline less than 25 is found in only 5 hip joints

These figures should indicate that a large angle of incline certainly is a feature in the picture of a hip joint dysplasia but as previously stated I would not venture on the basis of the present radiological findings

to draw up any boundary between normal and pathological angles of incline

A circumstance which caused the author some thought during the collection of the material was the danger of overlong irradiation of the gonads. As the figures from the casepresentation will show, an attempt was made to cover the gonads with lead plate during the exposure.

In this field my experience is that it is difficult to achieve satisfactory covering of the gonads, at any rate in girls, without at the same time covering parts of the hip joints. It may therefore be asked if it is more advisable to take the pictures without covering than to present the patient for two or more exposures in order to include both hip joints.

Skin dosage in exposure of the joints was measured. This is of such a degree that a control examination at intervals of 3 months will scarcely cause any injury to the gonads. I would, however, emphatically warn against exaggerated use of X-ray examination, not least because the clinical examination may be of more value than the radiological examination in newborns.

e) Treatment with Frejka's cushion splint

My experience with Frejka's cushion splint has been very favourable. In the great majority of cases I obtained normal development of the hip joints after 3 month's treatment. In certain cases where instability was unusually large or where treatment began later than the newborn stage I utilised plaster immobilisation for a short period. In these cases I replaced the plaster by a cushion splint after 3–4 weeks and found this completely satisfactory.

The advantage of the cushion splint is that it causes the patients little or no inconvenience. It also is simple and cheap to make and easy to take off and put on in the daily care of the baby.

f) The results of other clinical observations of the child

The information which I have collected about the length and weight of the child at birth shows considerable correspondence with the average figures for the country. Length and weight relationships in the series therefore give no support to the theory that space conditions in the womb are an etiologic factor in h. d.

As far as the position of the foetus in the womb is concerned, conditions on the whole agree with what is found in a normal material with the exception that breech position occurs more often than usual

6 children or 12 % were born in the breech position This also corresponds with what is found in other series It is asserted in the literature that children are born in the breech position because they are not large and are more delicate than others and that their leg movement in the womb would therefore be less active I find no support for this theory if length and weight are to form an expression of muscle activity The average weight of the 6 children born in the breech position is 3 (gr thus somewhat above the average for the whole series This is in spite of the fact that one of these 6 children is a twin

I also noted the mother s age at birth to see if this could have any importance in the etiology The average age of the mother was 29 9 years The series includes two cases of twins In calculating the above figures I included the age of these mothers twice If this error is corrected an average age of 29 4 years results The average age of 93 mothers with normal children amongst the 3242 examined equals 29 3 years and therefore this forms no reason for the assertion that the mother s age has any significance in the development of h d

As with other series definite information about other cases of h d in the family to a high figure were found in this series the figure was 34 % Moreover it may be said that several children in the series are related Finally it ought to be stated that amongst the 50 children 3 pairs of twins were affected I found h d in both twins in two of the pairs This also supports the theory of the familiar emergence of h d

On the basis of the information gathered about the length and weight of the children at birth their foetus position their order of birth in the family the mother s age at birth and other cases of h d in the family one can only draw the conclusion that h d occurs more often in children born in the breech position than in other foetus positions and that the disease seems to be conditioned by the respective family facts which were well known from previous research

SUMMARY AND CONCLUSION

The results are presented of an investigation into hip joint dysplasia in all children born at County Hospital in Ålesund Norway in the years 195) 57 in all 3242 children The findings indicate an incidence of morbidity far above the accepted average for Norway

On the basis of the series presented it is thought that these conclusions may be drawn

1. A clinical examination of the hip joints of all newborns should be consistently pursued.
2. A positive Ortolani's sign or a definite instability of the hip when demonstrated in newborns is a convincing symptom of hip joint dysplasia which demands treatment. Treatment should be commenced immediately after birth.
3. The normal hip joint in newborns can be moved passively with complete freedom without any form of crepitation. A repeated and constant crepitation in a certain position of the hip joint may indicate the presence of a dysplasia and ought to lead to control examination of the baby at 4 months of age when the epiphysis is radiologically visible.
4. Limitation of abduction in the hip joint occurs rarely or never in in newborns as a sign of hip joint dysplasia.
5. In newborns clinical examination of the hip joints is so superior to X-ray examination that the latter can be dropped without consequences. It is only when the epiphyses becomes visible radiologically that the X-ray offers more than the clinical examination.
6. The reduction position achieved in the hip joints with a Frejka's cushion splint in children up to 9 months of age is completely satisfactory and will in the great majority of patients provide recovery.
7. Treatment of hip joint dysplasia with Frejka's splint is so little troublesome to the patient and mother that commencement of treatment is justified even if there may be doubt about the diagnosis.

RÉSUMÉ ET CONCLUSION

Présentation des résultats de l'examen concernant la dysplasie de l'articulation de la hanche pratiqué chez tous les enfants nés à l'Hôpital Fylke à Alesund en Norvège dans les années 1955–57, en tout chez 3242 enfants. Les trouvailles indiquent une incidence de morbidité beaucoup plus élevée que la moyenne normalement présumée en Norvège.

Sur la base de cette série d'observations on considère que les conclusions suivantes peuvent être tirées:

1. Il faut continuer à procéder à un examen clinique des articulations de la hanche chez tous les nouveau nés.

2. Un signe Ortolani positif ou une instabilité définie de la hanche constatée chez un nouveau né un symptome certain de dysplasie de l'articulations de la hanche qui demande à être traitée. Le traitement doit être entrepris immédiatement après la naissance.

3 Le mouvement passif d une articulation normale de la hanche chez les nouveau nes est entierement libre sans aucune forme de crepitation Une crepitation répetee et constantee dans une certaine position de l articulation de la hanche indique la presence d une dysplasie et doit engager a un examen de controle du bebe a l age de 4 mois lorsque l epiphyse est radiologiquement visible

4 La limitation de l abduction de l articulation de la hanche est rarement ou jamais constatee chez les enfants comme signe de dysplasie de l articulation de la hanche

5 Chez les nouveau nes l examen clinique de l articulation de la hanche est si superieur a l examen aux Rayons X que celui ci peut etre abandonne sans inconvenient C est seulement quand l epiphyse devient visible radiologiquement que les Rayons X donnent plus que l examen clinique

6 La position de reduction pratiquee dans les articulations de la hanche au moyen d une attelle Frejka chez les enfants jusqu a l age de 9 mois est completement satisfaisante et entraine la guerison dans la grande majorite des cas

7 Le traitement de la dysplasie de la hanche par l attelle Frejka est si peu genant pour le bebe et sa mere qu il est justifie de l entreprendre meme si l on a des doutes concernant le diagnostic

8 Les resultats obtenus par le traitement conforme de la dysplasie de l articulation de la hanche chez les enfants sont si bons qu il devrait etre possible dans un proche avenir de rayer les dislocations de la hanche comme probleme orthopedique chez les enfants plus ages ou les adultes

9 Les donnees presentees concernant la position de l enfant dans la matrice la longueur et le poids apres la naissance n offrent aucune base a l explication méc inique d une dysplasie de l articulation de la hanche

ZUSAMMENFASSUNG UND SCHLUSSFOLGERUNGEN

Die Ergebnisse einer Untersuchung der Huftgelenksdysplasien aller Kinder die in den Jahren 1955–57 am Fylkes (Bezirks) Krankenhaus in Alesund Norwegen geboren wurden (insgesamt 3242 Kinder) wer den vorgestellt Die Befunde weisen eine Haufigkeit der Morbiditat auf die weit hoher als der angenommene Durchschnitt fur Norwegen ist

Auf Grund der vorgewiesenen Untersuchungsreihen glaubt man die folgenden Schlussfolgerungen ziehen zu konnen

1. Eine klinische Untersuchung der Hüftgelenke aller Neugeborenen sollte konsequent vorgenommen werden.

2. Ein positives Ortolani Zeichen oder eine sichere Unstabilität der Hüfte sind, sobald sie am Neugeborenen nachgewiesen werden, überzeugende Symptome einer Gelenksdysplasie und erfordern Behandlung. Diese soll unmittelbar nach der Geburt begonnen werden.

3. Das normale Hüftgelenk des Neugeborenen kann passiv vollständig unbehindert und ohne jegliche Krepitation bewegt werden. Eine wiederholte und konstante Krepitation in einer gewissen Stellung des Hüftgelenkes kann das Vorhandensein einer Dysplasie anzeigen und sollte zu einer Kontrolluntersuchung des Kindes im Alter von 4 Monaten, wenn die Epiphyse im Röntgenbilde sichtbar wird, führen.

4. Begrenzung der Abduktion im Hüftgelenk des Neugeborenen ist als ein Zeichen von Dysplasie kaum oder niemals vorhanden.

5. Bei Neugeborenen ist die klinische Untersuchung des Hüftgelenkes der Röntgenuntersuchung weitaus überlegen, so dass die letztere ohne Folgen fallen gelassen werden kann. Nur sobald die Epiphyse röntgenologisch sichtbar wird, bietet das Röntgenverfahren mehr als die klinische Untersuchung.

6. Die Einrenkungsstellung im Hüftgelenk, welche mit Frejkas Pol*sterschiene erzielt wird, ist bei Kindern bis zu 9 Monaten* vollständig zufriedenstellend und wird für die Mehrzahl der Patienten eine Heilung ergeben.

7. Die Behandlung der Hüftgelenksdysplasie mit der Frejka Schiene stört Kind und Mutter so wenig, dass die Inangriffnahme der Behandlung berechtigt ist, selbst wenn Zweifel über die Diagnose bestehen.

8. Die Ergebnisse einer konsequenten Behandlung der Hüftgelenksdysplasie bei Säuglingen sind so gute, dass es möglich sein sollte, Hüftgelenksverrenkungen bei älteren Kindern und Erwachsenen als ein orthopädisches Problem in der nahen Zukunft auszuschalten.

9. Die vorgelegten Daten über die Lage des Kindes im Uterus, ferner über Länge und Gewicht bei der Geburt bieten keine Grundlage für eine mechanische Erklärung der Entwicklung von Hüftgelenksdysplasie.

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TOMOGRAPHY AS AN AID IN EVALUATING THE RESULTS OF SURGERY IN EPIPHYSIOLYSIS

By

ANDERS LIDSTROM

The surgical treatment of epiphysiolysis basically consists in fixation of the epiphysis by means of one or more nails or screws of varying types. Both the simple method of osteosynthesis used when there is only a negligible degree of displacement and the technique which includes open reduction and possibly osteotomy adopted to correct more severe deformities are based on this principle.

Generally two plane roentgenograms are a satisfactory means of checking the position of the osteosynthetic material during and after operation. In a few cases, however, this photographic technique may not be adequate to determine the position of the fixation appliance with sufficient accuracy.

Billing in his monograph, published in 1954, has made an extensive study of these problems. He observes that the roentgen examination should provide information on the following three points:

1) The position of the nail tip in relation to the epiphyseal cartilage.

It is generally accepted, at least in Sweden nowadays, that the nail must bridge the epiphyseal cartilage and be firmly anchored in the epiphysis if a reliable osteosynthesis is to be achieved. In order to make it possible to check this from the roentgenograms, it is necessary that the radiation be applied in a direction parallel to the plane of the epiphyseal cartilage.

2) The position of the nail tip in relation to the articular surface of the femoral head.

In order to permit a direct evaluation from the roentgenogram, the direction of the radiation should be tangent to the surface of the femoral head at the point nearest the tip of the nail.

3) The position of the nail in the femoral neck.

Billing states that a roentgen technique which satisfies th
in all cases must be based on mathematically defined pro
due consideration given among other things to the angle fo
axis of the femoral diaphysis and the so called epiphyse
describes a modified technique in which the roentgenograms
and neck are taken at right angles to each other with the
directed vertically in both cases This assures that in the late
the direction of the radiation will be parallel to the epiphyse
The method requires that the hip be rotated strongly outwards a
knee joint flexed during exposure for the lateral view



Fig 1

In a great number of cases—for instances if a plaster fixation is to be applied following open reduction—such a mobilization of the hip and knee joints is not feasible Under those circumstances as shown in figures 1–5 tomography offers a solution which satisfies all the demands specified above

The advantages of the method are illustrated by figure 1 The epiphyseal line is clearly visualized and the picture confirms without a doubt that both nail tips are anchored in the epiphysis without touching the epiphyseal cartilage Likewise the position of the nails in the neck can be checked

In the case illustrated by figures 2 and 3 the first picture (figure 2) was taken by routine methods The direction of the radiation had not been parallel to the plane of the epiphyseal cartilage and "the epiphyseal line was not clearly delimitated The tomogram (fig 3) made



Fig 2



Fig 3

some days later showed that both nails had penetrated the epiphyseal cartilage

The patient in the other case illustrated by figures 4 and 5 was a 13 year old boy treated by open reduction and fixation with a corkscrew bolt When active motion of the leg was permitted following removal of the plaster fixation applied after operation considerable rigidity remained and attempts at forced mobilization were painful On roentgen examination by routine methods (fig 4) in which the radiation



Fig 4



Fig 5

had probably not been directed tangentially to the surface of the articular cartilage the nail tip was shown to penetrate to the bone cartilage junction The tomogram (fig 3) disclosed that the screw penetrated several millimeters into the joint space

Tomography therefore offers a technically simple and reliable solution to the problem of checking the position of the osteosynthetic material It is a suitable method in any case in which examination by routine methods proves inadequate It moreover would seem that the method can be a valuable aid at a later stage in the postoperative course in determining the degree of ossification of the epiphyseal line that has resulted from the osteosynthesis

SUMMARY

Based on the experience gained in 3 illustrative cases which are described the author calls attention to the value of tomography as a technically simple solution to the problem of checking the position of the osteosynthetic material in the surgical treatment of epiphyseolysis The method is particularly useful in cases where X ray examination by routine methods is inadequate

RÉSUMÉ

En se basant sur l expérience de 3 cas qui sont decrits l auteur attire l attention sur la valeur de la tomographie comme solution technique simple au probleme du controle du materiel osteosynthétique dans le traitement chirurgical de l epiphyseolyse La methode est particuliere ment utile dans les cas ou l examen aux Rayons X par les methodes routinieres n est pas appropríe

ZUSAMMENFASSUNG

Auf Grund der Erfahrung in drei typischen Fallen die beschrieben werden leitet der Verfasser die Aufmerksamkeit auf den Wert der Tomographie als eine technisch einfachte Losung des Problems der genauen Feststellung der Lage von osteosynthetischem Material bei der chirurgischen Behandlung der Epiphyseolyse hin Die Method ist besonders wertvoll wenn sich die gewohnliche Rontgenuntersuchung als unzulanglich erweist

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LOCALIZED OSTEITIS DEFORMANS

By

P. N. HENNEBERT M.D. and M. J. SEGHERS M.D.

Among the many cases of osteomyelitis seen by the orthopaedic unit there is a type of chronic osteomyelitis which has been of particular interest to us. There was no cavity or sequestra formation. The radiographic appearance and the visible deformation of the tibia led us to diagnose a very rare lesion described by *Lievre* (1936) under the name of "Remaniement pagetoide localise d'origine traumatique".

It is a type of osteitis deformans but remains localized and appears long after it the site of trauma. There follows a summary of two cases seen by us, the one involving the tibia, the other the fibula.

CASE REPORTS

Case 1. Miss N. L., aged 19, admitted to Lovanium clinic on March 11, 1953.

History. When three years old the patient sustained mild trauma to the left leg which rapidly became a dirty wound with generalized signs of toxemia. She was hospitalized and curetage of the tibia was carried out; skin grafting was later necessary to close the wound which remained indolent. From the age of three to the time of admission the formation of purulent ulcers frequently recurred interrupting the rare periods of apparent healing.

On admission. The patient presented with a painful swelling of the left leg which impeded walking. The leg was curved forwards. At the level of the anterior border of the tibia the skin was stretched and atrophic with areas of hyperpigmentation.

At the levels of the middle and lower thirds of the tibia were two ulcers, each of approximately 4 cm. in diameter overlying the anterior border of the tibia.

The skin was warm and showed increased sweating; examination of the leg provoked excessive sweating of the lower leg within a few seconds. There was no joint involvement.

Investigations. On X-ray examination comparison between the two tibias showed the following differences: a diffuse thickening of the whole diaphysis of the left tibia which was 1 cm. longer and bent forwards; the fibula was normal (Figs. 1 and 2). In its middle third the left tibia was twice as thick as the right one and it was difficult to distinguish between the cortex and the medulla, particularly at the anterior border. The structure of the bone was lamellar with an irregular criss

Fig 1 *Fig 2* *Fig 2 a*





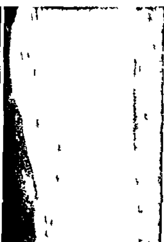




Fig 3

F g 1 The thickening of the left tibia is very important Disappearance of the limit b tween cortex and medulla Pseudo-cystic aspect f the lower third

F g 2 Lateral view The tibia is bent f r wards and the tructure of the anteri r bor der is lamellar

Fig 2 a Enlarg ment of one area of the Fig 2

Fig 3 Postoperative aspect h ll we l out t bia

cross patt rn and minute ca itie (Fig 2 a) The den its of the l ne w s er unequal oraque an l transpa ent areas w r irregularl dispo ed there were n visible questra The X r y appear n e of the skull lumbar spine and the pelvis were n rmal R utine blo d an l urine e aminati n h we l no ab n malitie

- E S R (Westergr n) 41 mm in one h ur
- S rum ph ph ru 4 6 mg
- S rum calcium 10 mg %
- Serum a id ph phat s — 0 14 B d n ky units

Serum alkaline phosphatase = 3 Bodansk units
Wassermann neg — Widal neg
Urine calcium (Sulkovitch) increased +++

Discussion of treatment The following aspects of this problem were considered

1 The covering of the ulcers with skin
2 The trophic disorders of the skin
3 The deformation of the tibia
4 The elimination of pain
5 The determination of the nature of the lesion (bone biopsy)

To realize these five aims we decided on the following operation resection of the anterior border of the tibia with hollowing out of the bone on the anterior medial two thirds lateral mobilization of skin suturing it over the thinned tibia

Treatment By a longitudinal elliptical incision the atrophic skin was excised the medial surface of the tibia on two third of its length was removed the anterior border of this bone was rectified The bone consistency was very softened the cortex was soft and the medulla was filled with cancellous bone abundantly vascularized A posterior lateral counter incision was made to cover the bony surface with healthy skin Later skin grafting was carried out to cover the defect of the counter incision and a small area of necrosis

Follow up The postoperative X ray showed the limits of the excavation in the lateral view the tibia seems to be well reestablished (Fig 3) The posterior cortex remains and appear strong enough whereas an important part of the fibrillar bone is removed Seen recently the patient was satisfied with the result pain disappeared and walking was easy The scar was good but the skin in this area was thin too pigmented and partially adherent to the deep tissues The general condition was quite excellent and control blood and urine examination gave similar results the excess calcium elimination in the urine persisted

Case 2 Mr P N 45 years of age

History When he was about twenty years old this patient sustained an injury just above the lateral malleolus which became ulcerated She was hospitalized elsewhere for one month before healing occurred Twenty five years later in 1958 a new ulcer appeared at the same site which persisted until admission to our hospital on april 27 1951

On admission The patient presented with a swelling of the ankle and of the lower third of the left leg Above the lateral malleolus an old ulcer of cm of diameter and 0.5 cm deep was situated over the fibula This whole area was warmer and showed the same focal symptom of hyperhydrosis as the first case Walking was painful The fibula was thickened and tender in its lower third There was no limitation of movement at the ankle joint

Investigations On X ray examination the left fibula was normal in its upper third lower it progressively thickened until its diameter was equal to that of the tibia (Fig 4 and 5) In its lower third the cortex could not be distinguished from the medulla the outline of the bone was very irregular hazy in some place and the degree of calcification was unequal There were no equestra visible The joint appeared normal but the lateral cortex of the tibia appeared to be slightly involved



Fig 4 *Fig 5* *Fig 6*

Fig 4 Progre sive thickening of the fibula from top t bott m
Fig 5 The lower third of the fibula has the same width as the tibia The cutline f the bone is irregular and hazy
Fig 6 Po toperative radi graphy

The X ray appearances of pel i and skull were normal the lumbar spine showed some les ons of arthrosis

Routine blood and urine examinations gave no mal result

- E.S R (Westergren) = 40 mm in ne h ur
- Serum pho phorus = 3 4 mg
- Serum calcium = 9 mg %
  Serum acid phosphata e = 0 18 Bodan ky unit
  Serum alkalin phosphatase = 39 Bodansk un t
  Wasserm nn = neg —Wid l = neg
- Urine cal ium (Sulko itch) in rea ed + +

Treatm nt The therap utic p oblem w milar t th t of the first ca e t relieve the pain and the ulcer to r luce th l f m t n f the l wer leg an l t study the hi t logy of the l n le ion On M 9 13 9 th ulcer and the low r tw thirds f the fibula were exci ed under t urniquet p t f the lateral malle l i was left to av id distortion f the ankl j int (Fig 6)

The w un l heal l rapidl an l th patient w lk d n m lly without p in Seen again in May 1960 ankle j int m ti n ha l r maine l f e an l painle

HISTOLOGY EXAMINATIONS

Professor *J Vincent* of Lovanium h is examined the bone biopsies of both patients The micro-r idiographic ispect shows an irregul ir Haver

sian architecture which resembles Osteitis Deformans of Paget but which is *nowhere characteristic* Generally there is a distinct lamellar structure The walls of the Haversian systems are frequently crossed by small vascular canals The amount of calcium in one haversian system and from one to another is variable just as in an normal bone (Fig 7)

Mc Manus method applied after decalcification of the fragments shows that coloration with PAS varies inversely in intensity with cal

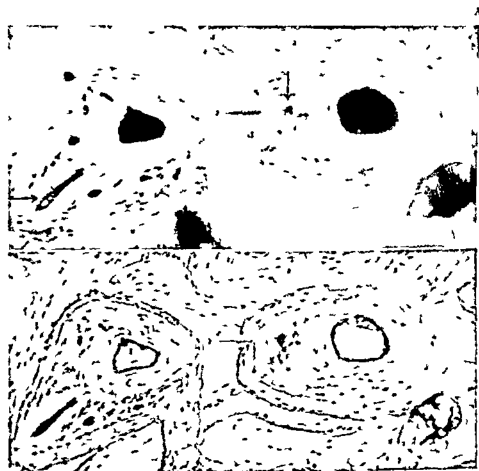
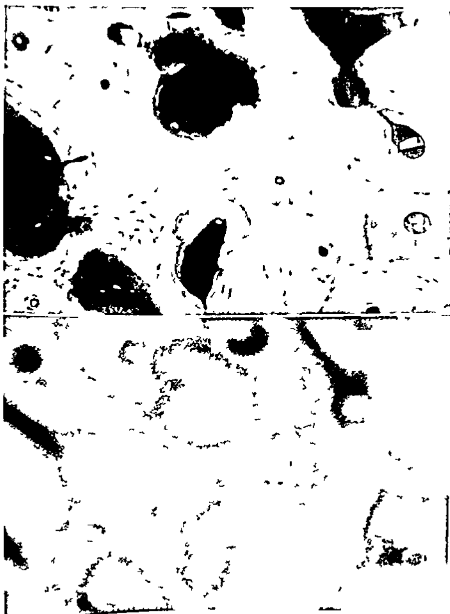


Fig 7

Correlation between the microradiograph (7 A) and the histological picture of the same slide after decalcification and coloration with PAS (7 B) The structure of the tissue is disturbed Two arrows indicate vascular canals in the wall of Haversian systems The essential bone substance is the more colorated by the method of Mc Manus that it was less calcified Enlargement 60 ×



B

Fig 8

Corr lation between the microradi graph (8 A) an l the aut r di graph made in vitr with S35 (8 B) l mellar di p ition Th ra lioactivity is in the le c lcifie l tis ue Enlargem nt 5 ×

cification Some preparations were dipped in vitro in a solution of $Na_2S^{35}O_4$. Recorded on a Dentus Rapid (Gevaert) film the autoradiography was compared with the microradiographic picture; it showed that the affinity for the S^{35} was limited to areas incompletely mineralized (Fig 8).

The day before the operation the second patient received intravenously Aureomycin (25 mg per kilo) in order to observe the bone fluorescence. The study of these sections in the extreme blue light brings out fluorescent rings around the largest of the haversian canals. These rings indicate in dogs the sudden and massive deposit of mineral salts (*Ghose*).

In conclusion these special investigations show no abnormalities in the constitution of the bone substance itself but they illustrate the irregular pattern of the haversian system similar to that seen in Osteitis Deformans.

The pictures of the two cases are similar.

DISCUSSION

Whereas the radiological appearance and the deformation of the tibia are in accord with the osteitis deformans of Paget, the histological aspect is a little different and leads us to consider a lesion described in 1936 by *Lievre* under the name of "Remaniement pagetoide localisé d'origine traumatique".

In 1936 *Lievre* described the clinical and radiological signs but it was only in 1957 that *F. Rohner* published the results of his histological investigations; he found a fundamental difference in the bone structure of the two lesions. In the osteitis deformans the structure of the bone is formed by many small irregular fragments all connected together by ramified fibres giving the pathognomonic aspect of "Mosaic Pattern".

In contrast in the localized Remaniement pagetoide the mosaic *pattern is rather rare and not as typical; the bone is constituted by* lamellae directed longitudinally; the connecting fibres are not as numerous.

The particular aspects of this syndrome are the following: initial trauma, localization, free interval, sex and age of the affected patients, clinical and radiologic signs. We intend to develop it and compare with the history of the two preceding cases.

– The initial trauma may be mild or violent; it causes at least a bony contusion with a sub periosteal hematoma. Sometimes it is strong enough

to cause a fracture as in the three cases of *Rohner* In our two cases the trauma was mild but was immediately complicated by serious infection This inflammatory aspect the long suppuration without elimination of sequestra is quite atypical and constitutes a particularity of our two African cases

– The most frequent localization is the tibia but others have also been described fémur skull and simultaneous involvement of the tibia and the fibula The superficial situation of these two bones exposes it to trauma and would explain their relative frequence

– The free interval usually lasts several years It is quite characteristic for the localzation on the fibula where for twentyfive years the patient had no complaints For the localization on the tibial diaphysis the interval was also of many years but this interval was not free frequent ulcers occurred during these sixteen years

– Generally women over the age of forty are affected Our first case with the age of three for the initial trauma and nineteen for the constituted lesion with bending of the tibia does not accord with this picture

– The clinical signs are convincing bone pain important hypertrophy of the involved bones bending of the tibia and local vasomotor disorders skin hyperthermia hyperhydrosis and abnormal pigmentation

– The radiological signs are similar to those seen in osteitis deformans hyperplasia of the bone in width increased length changes in the structure of the bone with disappearance of the limit between cortex and medulla unequal degree of calcification

What is the pathogenesis of this lesion? What is the underlying mechanism of its formation? Generally it is believed that the initial trauma causes vasomotor disorders in the involved bone *Rohner* points out this lesion could be a type of Sudeck's atrophy This hypothesis however can be discounted by the poor results given by sympathic infiltrations and sympathectomies

Treatment is generally disappointing sympathectomies radiotherapy give no success Local treatment may only be attempted for instance corrective osteotomy

Before the inflammatory aspect of our two cases we did not hesitate to excise the diseased skin and to remove an important part of the affected bone Our surgical treatment stopped the infected ulcers and the pain The long term prognosis remains however very reserved because we did not stop the vasomotor disorders and the bone altering as the urine calcium elimination tests showed

SUMMARY

Two further cases, the first in *Africa* of "Remaniement pagetoide localise" are described The number of cases now *published* is about twenty *Modern* histological methods confirm this as a well defined disease *entity*

Treatment by wide excision of bone gave a symptomatic cure in both these cases

RESUME

Deux nouveaux cas les premiers en Afrique de remaniement pagetoide localise sont decrits Le nombre des cas publies jusqu ici s eleve a *environ 20* Les *methodes histologiques modernes confirment* qu il s agit la d une bien definie

Le traitement *par* large excision osseuse a amene la guerison dans ces deux cas

ZUSAMMENFASSUNG

Zwei weitere Fälle der erste in Afrika von Remaniement Pagetoide Localise" werden beschrieben *Die* Zahl der bisher veroffentlichten Fälle ist ungefahr *zwanzig* Moderne histologische Methoden bestatigen die Erkrankung als eine wohlabgegrenzte Einheit

Die Behandlung mit weitgreifender Excision ergab eine symptomati sche Heilung in beiden Fallen

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EXCISION OF METATARSAL HEADS FOR PAIN UNDER THE ANTERIOR ARCH OF THE FOOT WITH WEIGHT BEARING

By

ANDERS LIDSTROM

Conditions in which weight bearing causes forefoot discomfort in the form of tenderness and corns under the metatarsal heads are particularly common in middle aged and elderly women and may be the cause of severe disability The treatment in such cases is aimed at preserving or improving function by relieving the pain and correcting the deformity which is usually present To this end conservative treatment is primarily indicated Relief from the pressure of weight bearing by means of some form of support in combination with technical measures to adapt the shoes usually achieve the desired result

Surgical treatment consequently is indicated in a small number of cases only and reserved for patients with particularly severe deformities or those whose condition has failed to respond to prolonged conservative treatment Soft tissue surgery such as tenotomy may at times be useful but as a rule it will be necessary to remove prominent bone which causes deformity In 1911 Hoffmann launched an operation for excision of the metatarsal heads in the English literature which has remained somewhat of a standard procedure and is mentioned as a useful alternative in most of the handbooks (*Nordisk Larobok i Ortopedi* for one) While the merits of the operation are unquestioned opinions differ in particular with regard to its extent Definite principles are lacking moreover to establish the indications for this form of treatment in various painful conditions of the forefoot Detailed follow up studies furthermore are scarce

It is generally accepted that feet which are deformed and painful as the result of rheumatoid arthritis are amenable to treatment by excision of one or more metatarsal heads (*Thomsen* 1937 *Key* 1950 *Clayton*

1960) "Severe grades of contracted or clawed toes due to other causes too were operated upon successfully by *Hoffmann* as early as 1911 The operation appears hardly ever to have been used on the other hand to relieve pain from weight bearing in cases without contracture of the forefoot for instance in Morton s disease and similar conditions

Hoffmann recommended excision of all five metatarsal heads and furthermore advised to remove enough of the remainder of the meta tarsal bone to permit unhampered movement of the phalangeal base down to the level of the metatarsal stump after operation Even more radical was *Clayton* s method in which the excision was extended to include part of the phalanges of all five toes *Thompson* on the other hand considered that only a prominent head subjected to undue pres sure from weight bearing should be excised so that the pressure might be equally distributed over the remaining metatarsal bones *Key* (1950) likewise recommended that only those parts of the foot skeleton be removed from which the symptoms emanated *Lewin* (1959) combined the operation with transplantation of the extensor tendons to the meta tarsal bones Otherwise the procedure has usually been varied only with respect to the incision Both dorsal and plantar transverse incisions have been used to perform extensive excisions while a longitudinal dorsal incision has been recommended for excision of a single meta tarsal head (*Campbell s Operative Orthopaedics*)

A follow up study has served as the basis for an evaluation of this operation In view of the background outlined in the foregoing two questions have been considered of primary interest

1) What value has the procedure in relieving discomfort from weight bearing in various types of foot disorders?
2) How extensive should the operation be in the different cases or in other words how many metatarsal heads should be excised?

MATERIAL

All of the 30 patients who made up the series were included in a follow up examination The total number of feet operated upon was 41 The interval between operation and follow up varied from 6 months to 4 years with an average of almost 2 years All but 1 of the patients were women The incidence reached a peak in the age groups between 50 and 70 years (Table 1)

The most common symptoms were pain from weight bearing ten derness on palpation and corns under one or more metatarsal heads It

TABLE 1
Age Distribution

20–30	31–40	41–50	51–60	61–70	71–80
2	4	3	9	9	3

was remarkable that the symptoms in all but one of the cases were localized to the region under the second to fourth metatarso phalangeal joint

With respect to the question posed under 1) the patients were divided into two categories to wit cases with and without contracture of the forefoot The first group included all cases in which the foot presented the typical picture of luxation of the phalangeal base in the four lateral toes with the base of the phalanx due to shortening of tendons ligaments and other soft structures displaced onto the upper surface of the metatarsal head and pressing the metatarsal bone downwards It was considered essential that the deformity should be rigid and not amenable to manipulative reduction The material included 31 feet of this type 19 of them in patients with manifest rheumatoid arthritis In 27 of these cases the deformity was combined with hallux valgus of varying severity which in 11 cases was corrected by a Reverdin operation prior to or in combination with excision of the metatarsal heads

In a few of the 10 cases without contracture of the foot the presented symptom was a *single painful corn In the other cases in this group* the complaint was a distinct pain under a metatarsal head without any objective signs of disorder To some extent these symptoms were suggestive of Morton s disease and in a number of cases resection of the digital nerve had been performed without effect on the condition Insufficiency of the anterior arch and subluxation of the phalangeal bases of the toes could to some extent be observed in cases of this type too but the foot was invariably flexible and amenable to reduction As is only natural in a clinical division of this kind a few dubious cases were encountered but on the whole the classification presented no problems

Theoretically excision of a metatarsal head implies the removal of a weight bearing surface that may be valuable For this reason the extent of the operation tended at first to be limited and only the metatarsal heads over the painful regions were excised Later on guided by experience more extensive excisions were performed In 13 cases the second third and fourth metatarsal heads were removed in 9 cases the operation involved the second and third head and in 19 cases only one head was

excised Excision of the four lateral or all five metatarsal heads was in no case considered justified A plantar incision was used in all cases longitudinal for excision of a single metatarsal head otherwise transverse

Clayton (1960) has stressed the importance of immobilizing the foot after operation in the corrected position by means of a properly fitted plaster bandage This technique was adopted in the latter part of the series subjected to more extensive excision The bandage was left on for 2-3 weeks after which full weight bearing was permitted

RESULTS

In evaluating the results it should be stressed that the operation by no means produced a normal foot Even though extensive excision could make a contracted foot more flexible residual deformity in most cases required the continued use of supports or specially made shoes The aim of the treatment was necessarily restricted to relieving pain from weight bearing as much as possible with considerably improved function as a concomitant result

In evaluating the results of treatment therefore the material was divided into 3 groups according to the following criteria

1) Complete relief from pain with weight bearing
2) Considerable improvement but some residual tenderness with weight bearing
3) No improvement

Expressed in figures this evaluation gave the following results for the total series freedom from pain in 19 cases (46 %) improvement in 14 cases (34 %) no improvement in 8 cases (20 %) (Fig 1)

If the material is classified according to the two relevant factors i e type of disorder and extent of operation it falls into four groups with considerable variation in the results of treatment (Fig 2) In the group of 10 cases without contracture of the foot the operation was without exception limited to one metatarsal head The results were fairly satisfactory with only one patient showing no improvement whereas 8 were entirely free from pain Among the patients with contracted feet the results were most satisfactory in the group of 13 cases in which the operation involved excision of the second third and fourth metatarsal heads All patients in this group showed improvement and 8 of them (62 %) obtained complete relief from pain despite the fact

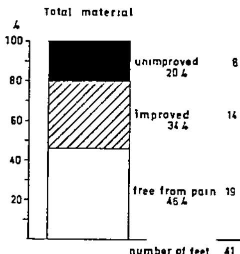


Fig 1

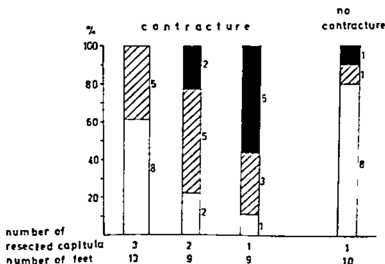


Fig 2

that the preoperative deformity tended to most severe in this group The results were decidedly poorest in the group of 9 patients with this type of foot disorder where only one metatarsal head was removed 5 patients showed no improvement at all and complete relief from pain was obtained in only 1 case

DISCUSSION

In the majority of cases with unsatisfactory results the patients reported that pain from weight bearing had recurred after an initial improvement during the first few months after operation. The removal of one pressure area had created new ones. It was remarkable that these recurring symptoms in all but one of the cases were localized to the second, third and fourth metatarsal heads. It seemed as though the three middle metatarsal heads in contracted feet formed a functional unit which had to be removed in its entirety. The satisfactory results in the cases where the operation had this extent suggested that primary excision of all metatarsal heads, as recommended by *Hoffmann*, is hardly justified with a view to providing relief from pain. It is, on the other hand, possible that such a more radical operation may produce better cosmetic results with a more flexible foot that is better amenable to correction.

In the one case in the group without contracture where the condition showed no improvement, the residual symptoms were localized to the operation site. Roentgen examination disclosed that part of the metatarsal head had been neglected in the excision. The same omission appeared to be responsible for some cases of residual tenderness over the metatarsal stumps among the patients with contracted feet who, although showing improvement, were not entirely free form pain. This illustrates the importance of being sufficiently generous in the removal of bone in this kind of operation on the forefoot.

Although the available material is not very large, it permits the following preliminary answers to the questions posed at the beginning of this paper.

1) Excision of metatarsal heads is a useful procedure for relieving pain under the anterior arch from weight bearing, both in rigid deformed feet and in feet without contracture.
2) Where the former type of foot is concerned the operation should include the second, third and fourth metatarsal heads. In non-rigid feet the excision can be limited to the metatarsal head over the area which is painful with weight bearing.

SUMMARY

The effect of the excision of metatarsal heads on pain from weight bearing in the sole of the forefoot is analyzed on the basis of a follow-up examination of 41 feet treated by this operation.

In the group comprising 31 f et with a rigid forefoot in 19 cases in patients suffering from rheumatoid arthritis a satisfactory result was achieved if the excision included the second third and fourth metatarsal heads With less extensive surgery weight bearing symptoms in a large number of cases recurred under the remaining heads

In the smaller group of 10 cases in which the foot was not contracted it proved sufficient to remove only the metatarsal head over the area affected by pain from weight bearing

RESUME

L effet de l excision des tetes metatarsiennes en cas de douleur provenant de la charge du poids sur la plante anterieure du pied est analyse sur la base d examens complementaires de 41 pieds traites par cette opération

Dans le groups comprenant 31 pieds avec partie anterieure du pied rigide il a éte obtenu chez 19 malades souffrant d arthrite ruhmatoide un resultat satisfaisant lorsque l excision comprenait les 2eme 3eme et 4eme tetes métatarsiennes Avec une intervention moins extensive les symptomes provopués par la charge du poids reapparaissent sous les tetes qui restent

Dans le plus petit groupe de 10 cas chez lequel le pied n etait pas contracte il s est avere suffisant de n enlever la tete metatarsienne qu a l endroit ou la charge du poids provoquait des douleurs

ZUSAMMENFASSUNG

Die Wirkung der Exzision von Mittelfusskopfchen auf die Schmerzen die bei der Belastung in der Sohle des Vorfusses auftreten wird auf Grund einer Nachuntersuchung von 41 mittels dieser Operation behandelten Fussen analysiert

In der Gruppe die 31 versteifte Vorfusse davon 19 Falle von chronischem Gelenksrheumatismus umfasst wurde ein zufriedenstellendes Ergebnis erzielt wenn die Exzision das zweite dritte und vierte Mittelfusskopfchen einbezog Bei weniger ausgedehntem chirurgischem Eingriff traten die Belastungssymptome in einer grossen Anzahl der Falle unter den zuruckbleibenden Kopfchen wieder auf

In der kleineren Gruppe von 10 Fallen in denen der Fuss nicht fixiert war erwies es sich als ausreichend nur das Mittelfusskopfchen im Gebiete des Belastungsschmerzen zu entfernen

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